THE EFFECTIVENESS OF DIMENSIONAL ANALYSIS AS A PROBLEM-SOLVING METHOD FOR MEDICATION CALCULATIONS FROM THE NURSING STUDENT PERSPECTIVE

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by Gloria P. Craig
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The problem.

The nursing literature has identified that many nurses experience difficulty in calculating medication calculation problems. Chemistry educators have adopted a method, dimensional analysis, that is not only easier to learn but also reduces errors when a mathematical conversion is required. The purpose of this qualitative study was to evaluate the effectiveness of dimensional analysis as a problem-solving method for medication calculations from the perspective of nursing students. Specifically, the study answered the grand-tour question, "What perceptions do nursing students have regarding the effectiveness of dimensional analysis as a problem-solving method for medication calculations?" Based on the nursing literature, four sub-questions also were included regarding mathematical, conceptual, and cognitive deficiencies and mathematical anxiety levels of nurses and nursing students.

Procedures.

A purposeful sampling was utilized with 27 nursing students enrolled in a three-year diploma nursing education program from a hospital-based school of nursing located in central Iowa. To establish trustworthiness of the study, triangulation of the data was accomplished through the use of participant observation, one-to-one, open-ended interviews, and a closed-ended questionnaire allowing conclusions to be draw from multiple referents. Six nursing students requesting additional tutoring were chosen to participate in one-to-one, open-ended interviews based on the criteria for critical case sampling permitting maximum application of information.

Findings.

Data obtained from the nursing students provided themes and conceptual patterns regarding the effectiveness of dimensional analysis as a problem-solving method for medication calculations. Nine emerging themes were obtained from the data examples provided by the six nursing students during the open-ended interviews and categorized into three major conceptual patterns.

Closed-ended questionnaires were answered by 27 nursing students. All of the nursing students strongly agreed and agreed (100%) that dimensional analysis improved their mathematical calculation abilities and conceptual abilities, 92.6% strongly agreed and agreed that it improved their cognitive abilities, and 77.8% strongly agreed and agreed that it reduced their anxiety levels when solving medication calculation problems.

Conclusions.

In this study, nursing students identified that dimensional analysis was an effective problem-solving method for medication calculations that assisted them in improving their mathematical, conceptual, and cognitive abilities, as well as decrease their anxiety levels. Dimensional analysis was found to be a successful problem-solving method for both right-brain and left-brain learners because of the ability to be visualized and followed in a logical manner with an explicit step-by-step approach.

Recommendations.

The positive findings from this study certainly warrant further quantitative and qualitative research using dimensional analysis as a problem-solving method for medication calculations with other nursing students, students in other disciplines, and practicing nurses. Regardless of whether dimensional analysis is used in education or practice, it remains an avenue to be considered by schools of nursing, hospitals, or other institutions when the goal is competence in medication calculation abilities, reduction of medication errors, and above all adherence to the code "do no harm."

Tables

Chapter 1
INTRODUCTION

Overview of the Problem

Every nurse must know and practice the five rights of drug administration: the right drug, the right dose, the right route, the right time, and the right patient. Although nurses may be able to identify the right drug, route, time, and patient, the right dose requires mathematical, conceptual, and cognitive skills that may pose difficulty for some individuals and may be compounded by mathematical anxiety related to a "mathophobia."

To investigate medication calculation errors, Bindler and Bayne (1991) conducted a descriptive research study using a convenience sample of 110 registered nurses from four western states. They concluded that 81% of the registered nurses were unable to calculate medication doses at a 90% level of proficiency on a 20-item medication calculation test. In addition, they found that 43.6% of the test scores were below the 70% level of proficiency. The investigators suggested that this unsatisfactory performance level should be a major concern for nurse educators and proposed that the most effective way to improve the mathematical calculation abilities of registered nurses would be to integrate a specific problem-solving methodology into nursing curricula.

Nursing education programs attest that they graduate safe, first line practitioners. Some researchers asserted, however, that this may be a misconception (Bindler & Bayne, 1991). In a previous descriptive study conducted by Bindler and Bayne (1984), the basic mathematical skills of 741 junior baccalaureate nursing students were tested. Bindler and Bayne reported that from 9% to 38% of the student groups tested were unable to pass all parts of the Mathematics Proficiency Exam at the 70% level of proficiency. The authors concluded that a substantial number of the nursing students did not possess the basic mathematical abilities necessary to function as registered nurses. They strongly recommended that schools of nursing take an active role in identifying these students and finding methods to improve their mathematical abilities.

Although much of the research has been focused on the mathematical or computational skills of nursing students, Blais and Bath (1992) conducted a quantitative study to analyze the dosage calculation errors of nursing students from conceptual, mathematical, and measurement perspectives. They obtained a convenience sample of 66 nursing students enrolled in an upper-division baccalaureate nursing program at a large public university.

Blais and Bath focused on determining how many students lacked the skills to accurately calculate drug dosages on a 20-item medication dosage calculation examination and what type of error occurred most often including the frequency. The results revealed that 89% of the students did not perform at a 90% level. Conceptual errors (set-up of the problem) were the most frequent type of mistake in 56% of those problems missed. Errors involving mathematical deficiencies occurred in 19% of the problems and measurement errors (converting between different measurement systems) occurred in 13% of the problems. Bath and Blais concluded that, although students do have difficulty with mathematical and measurement deficiencies, the majority of the deficiencies involve conceptual difficulties. They recommended that schools of nursing focus not only on assisting the students with problem-solving strategies to conceptualize the dosage calculation problem, but also to be consistent throughout the curriculum with the type of formula the students are instructed to use.

Using a pretest/post-test quantitative design to examine mathematical abilities, Ptaszynski and Silver (1981) identified that the problem of poor calculation skills exists in other nursing programs. They found that nursing students entering baccalaureate nursing programs also have difficulty with dosage calculation because of a decline in SAT scores and varying degrees of mathematical background. They speculated that given these two variables along with the unit dose system used for medication administration, the problem of poor calculation skills is only compounded.

In an attempt to rectify the situation, Ptaszynski and Silver (1981) introduced posology (the study of dosage calculations) in an orderly, systematic fashion into an integrated curriculum through use of self-learning packets. The self-learning packet contained specific terminal objectives and was developed for the first level nursing students focusing on the cognitive learning levels of knowledge, comprehension and application, using ratio-and-proportion as a mathematical problem-solving method.

Ptaszynski and Silver (1981) administered a pretest during the first week of the semester before any formal medication education. The post-test was administered after the conclusion of the posology module. Of the 77 nursing students included in the study, the results of the pretest included a mean score of 52% with a range of 33% to 81% as compared to the results of a post-test mean score of 92.7% with a range of 76% to 100%. The study revealed that an organized problem-solving method to resolve medication problems can effectively increase the mean score from pretest to post-test. A high-level of acceptance of the posology program was determined through written and verbal evaluative feedback from faculty and students. The result of this acceptance led to the development of a second-level posology course focusing on the calculation and administration of intravenous solutions.

Historically, it has been reported that females experience higher levels of mathematical anxiety than their male counterpart (Betz, 1978). Although a limited amount of research exists in the nursing literature regarding mathematical anxiety, Hendel and Davis (1978) suggested a desensitization program as a means of lowering anxiety and improving performance. A computer-assisted instruction program developed by Timpke and Janney (1981) provided students with the opportunity to work in privacy and at their own speed which decreased levels of anxiety and increased confidence. Fulton and O'Neill (1989) suggested that nurse educators should no longer assume that female students are mathematically challenged and therefore possess high levels of anxiety. On the other hand, Pozehl (1996) concluded that nursing students do suffer from mathematical anxiety and need a learning environment that is structured to help them attain a positive attitude toward mathematics.

Information obtained from the nursing literature identified that medication errors do occur related to mathematical calculation deficiencies, however, the educational literature of another discipline offered a possible solution to the problem of mathematical calculation deficiencies. Goodstein (1983) established that a majority of chemistry students were deficient in their ability to deal with the quantitative aspects of subject matter. In an effort to improve the quantitative abilities of chemistry students, the chemistry educators utilized a problem-solving method called dimensional analysis (also called factor label method, conversion-factor method, units analysis, and quantity calculus). Goodstein expressed that even though the ratio-and-proportion method was at one time the primary problem-solving method, it has been largely replaced by a dimensional analysis approach in most introductory chemistry textbooks.

Dimensional analysis was identified in chemistry textbooks as a problem-solving method as early as 1938. Frey (1938) defined dimensional analysis but did not specifically explain how this method could be used to solve chemistry problems. Johnson (1969) defined dimensional analysis and described why this problem-solving method should be used to solve chemistry problems. He did not explain, however, how this method could be used to solve chemistry problems. Goodstein (1983) described dimensional analysis as a problem-solving method that is very simple to understand, reduces errors, and requires less conceptual reasoning power to understand than does the ratio-and-proportion method. She stated that this method condenses multi-step problems into one orderly extended solution.

Hein (1983) described dimensional analysis as a useful method for solving a variety of chemistry, physics, mathematics, and daily life problems. He identified that dimensional analysis is often the problem-solving method of choice because it provides a systematic, straightforward way to set up problems; gives a clear understanding of the principles of the problem; helps the learner to organize and evaluate data; and assists in identifying errors in that unwanted units are not eliminated if the setup of the problem is incorrect.

Peters (1986) identified dimensional analysis as a method used for solving not only chemistry problems but also a variety of other mathematical problems that require conversions. He described dimensional analysis as a method that can be used whenever two quantities are directly proportional to each other and one quantity must be converted to the other using a conversion factor or conversion relationship. Once the given quantity is identified, the unit path (the series of unit conversions necessary to achieve the answer) is established. He summarized the problem-solving method of dimensional analysis as follows:

Problem: 3 yards = How many inches?

1. Begin with the given quantity.

   Example: 3 yards

2. Establish the unit path from the given quantity to the wanted quantity, selecting the equations which will be used as conversion factors.

   Example: 1 yard = 3 feet

   Example: 1 foot = 12 inches

3. Write the setup for the problem, multiplying and dividing in a logical sequence through each step of the unit path. Given quantity x (One or more conversion factors) = Wanted quantity.

   Example: 3 yards = How many inches?

$$3 \text{ yards} \times \frac{3 \text{ feet}}{1 \text{ yard}} \times \frac{12 \text{ inches}}{1 \text{ foot}}$$

   Note that every conversion factor is a ratio of units which equals one.

4. Cancel units to be certain that the setup gives an answer expressed in the correct units.

   Yards cancel. Feet cancel. Inches remain as the desired unit.

   Example: 3 yards x $\frac{3 \text{ feet}}{1 \text{ yard}}$ x $\frac{12 \text{ inches}}{1 \text{ foot}}$ =

5. Multiply the numerators, multiply the denominators, and divide the product of the numerators by the product of the denominators to provide the numerical value of the answer.

   Example: 3 yards x $\frac{3 \text{ feet}}{1 \text{ yard}}$ x $\frac{12 \text{ inches}}{1 \text{ foot}}$ = 108 inches

Although there exists a paucity of research in the nursing literature regarding dimensional analysis, Craig (1993) conducted a quasi-experimental research study to examine whether the use of dimensional analysis would improve the medication dosage calculation abilities of nursing students. Specifically, the study compared the medication dosage calculation abilities of 30 diploma nursing students (experimental group) who were taught dimensional analysis with the medication dosage calculation abilities of 29 associate-degree nursing students (control group) who were taught the traditional problem-solving methods of ratio-and-proportion or desired dose/dose on hand. To determine if the increased level of improvement between the pretest and post-test scores of the experimental group was significantly greater than the control group, an independent t-test of the mean differences between the pretest/post-test scores of the experimental and control groups was applied. A statistically significant difference in the level of improvement was found between the two groups ($p=.00001$). The findings of the study support the use of dimensional analysis as an effective problem-solving method to assist nursing students in developing the mathematical and conceptual skills to accurately calculate medication dosages and ensure the safe administration of medications.

The nursing literature has identified that many nurses experience difficulty in calculating medication doses. Chemistry educators have adopted a method that is not only easier to learn but also reduces errors when some type of mathematical conversion is required. Nurse educators should be interested in the use of dimensional analysis as a method to improve the mathematical abilities of their students. The question, however, still remains as to whether nursing students using dimensional analysis perceive an improvement in their mathematical, conceptual, and cognitive abilities as well as a decrease in their anxiety levels.

Purpose of the Study

The purpose of this qualitative study was to evaluate the effectiveness of dimensional analysis as a problem-solving method for medication calculations from the perspective of nursing students. Specifically, the study answered the grand-tour question, "What perceptions do nursing students have regarding the effectiveness of dimensional analysis as a problem-solving method for medication calculations?" Based on the nursing literature regarding deficiencies in basic mathematical skills, medication calculation errors, conceptual and measurement problems, and mathematical anxiety levels, four sub-questions also were researched:

1. What perceptions do nursing students have regarding dimensional analysis and their mathematical calculation abilities?

2. What perceptions do nursing students have regarding dimensional analysis and their conceptual abilities?
3. What perceptions do nursing students have regarding dimensional analysis and their cognitive abilities?
4. What perceptions do nursing students have regarding dimensional analysis and their anxiety levels?

Definition of Terms

The terms used for this study were defined as follows:

Dimensional analysis - Dimensional analysis was defined as a problem-solving method that can be used to calculate medication dosage problems whenever two quantities are directly proportional to each other and one quantity must be converted to the other using a conversion factor or conversion relationship.

Nursing students - Nursing students were defined as those students enrolled in a three-year diploma nursing program located in central Iowa.

Mathematical abilities - Mathematical abilities were defined as those abilities concerned with mathematics that are very precise and accurate.

Conceptual abilities - Conceptual abilities were defined as the ability to set up a mathematical problem in a logical manner.

Cognitive abilities - Cognitive abilities were defined as the knowledge and understanding of how to solve a mathematical problem.

Anxiety - Anxiety was defined as worry or uneasiness about solving medication calculation problems.

Perceptions - Perceptions were defined as knowledge obtained by understanding through personal insight.

Overview of the Theoretical Framework

According to cognitive theory, learning is dependent on how information is structured, organized, and conceptualized. It involves associations established according to the principles of contact and repetition. Learning is viewed as involving the acquisition or reorganization of cognitive structures through which humans process and store information. The items of information acquired through learning are sorted, filed, and cross-indexed. This allows for meaningful learning and retaining of information in an organized fashion (Good & Brophy, 1989). Dimensional analysis is a problem-solving approach that is based on cognitive theory.

Significance to Nursing Education

Two studies regarding mathematical abilities or the lack of mathematical abilities of registered nurses have suggested that nurse educators should be concerned about the mathematical skills of practitioners (Bindler & Bayne, 1991; 1984). Although these studies were performed by the same researchers, the time span demonstrated that after seven years the problem with the lack of mathematical skills of nurses continued and had not improved.

Other studies also have identified factors that affect the mathematical calculation abilities of nurses. Worrell and Hodson (1989) proposed and verified that inconsistencies do exist between teaching methodologies of nursing faculty members. To demonstrate the problem of inconsistencies, they asked faculty of 221 nursing programs to demonstrate how they would set up a medication problem. They obtained 108 set-up variations that differed in the consistency of labeling and the use of mathematical formulas from the faculty members of the nursing programs. The findings offered an alarming picture of the inconsistencies a nursing student might encounter when being tutored by multiple nursing faculty.

In addition to the two major studies that have evaluated nursing students' computational abilities (Bayne & Bindler, 1988; Worrell & Hodson, 1989), other studies have been conducted that also identified that the difficulty with mathematical calculations seems to be the students' problem-solving abilities as opposed to computational skills (Blais & Bath, 1992; Chenger, Conklin, Hirst, Reimer, & Watson, 1988). Blais and Bath (1992) recommended that educators teach a method of problem solving that will allow students to conceptualize the problem by setting up their mathematical problems in a neat and organized manner that shows the flow of problem solving.

Although more current research is needed, anxiety can not be overlooked as a contributing factor to mathematical deficiencies. Females, comprising the majority of nurses, have historically been labeled as individuals with high levels of mathematical anxiety (Betz, 1978). Several methods for decreasing anxiety have been suggested such as a desensitization program, computer-assisted instruction, and creating a learning environment to promote positive attitudes toward mathematics (Hendel & Davis, 1978; Timpke & Janney, 1981; Pozehl, 1996).

The literature suggested that mathematical and dosage calculation deficiencies continue to be a problem within the nursing discipline. Calculation deficiencies among nurses or nursing students lead to medication errors that threaten patient safety and are costly in terms of malpractice litigation. Research included studies where ratio-and-proportion was used as a problem-solving method for medication calculations but the problem of medication errors still remains a significant concern. Chemistry educators previously using ratio-and-proportion have adopted dimensional analysis as a mathematical calculation method because it allows students to solve difficult problems involving multiple conversions. A quasi-experimental study by Craig (1993) concluded that dimensional analysis could be an effective problem-solving method that improved the medication dosage calculation abilities of nursing students. Although quantitative research studies have attempted to uncover the reason for medication errors and evaluate the use of ratio-and-proportion, no qualitative research has been conducted to explore the perceptions of the nurses or nursing students regarding mathematical calculation and medication errors using dimensional analysis. This qualitative evaluation study explored the perceptions of nursing students regarding the effectiveness of dimensional analysis as a problem-solving method that can be used to calculate medication problems that arise in clinical nursing practice.

Chapter 2
REVIEW OF THE LITERATURE

The purpose of this qualitative study was to answer the question, "What perceptions do nursing students have regarding the effectiveness of dimensional analysis as a problem-solving method for medication calculations?" This chapter is divided into three sections. The first section describes the theoretical framework used as the foundation for this study. The second section discusses research studies relevant to this study. The chapter concludes with a summary of the literature review.

Theoretical Framework

This study explored perceptions of nursing students regarding the effectiveness of dimensional analysis as a problem-solving method for medication calculations. Goodstein (1983) described dimensional analysis as a problem-solving method that is very simple to understand; reduces errors; requires less conceptual reasoning power to understand than other methods; and condenses multi-step problems into one orderly extended solution. Hein (1983) identified that dimensional analysis provides a systematic, straightforward way to set up problems; gives a clear understanding of the principles of the problem; helps the learner to organize and evaluate data; and assists in identifying errors in that unwanted units are not eliminated if the setup of the problem is incorrect. Peters (1986) described dimensional analysis as a method that can be used whenever two quantities are directly proportional to each other and one quantity must be converted to the other utilizing a conversion factor or conversion relationship. After the given quantity is identified, the unit path (the series of unit conversions necessary to achieve the answer) is established.

The concept of the problem-solving method of dimensional analysis is based on cognitive theory. In 1960, Bruner theorized that learning is dependent on how information is structured, organized, and conceptualized. He proposed a cognitive learning model that emphasizes the acquisition, organization (structure), understanding, and transfer of knowledge - focusing on "how" to learn, rather than "what" to learn. He purported that stimulus input received is actively perceived and interpreted in an organized fashion, using expectations developed from prior experiences.

Bruner (1966) viewed learning as an ongoing process of developing a cognitive structure for representing and interacting with new information. According to one of his principles of cognitive development, learning is possible because events are internalized into a "storage system" that amounts to an organized model. This "storage system" stores the information perceived and interpreted in the form of imagery, concepts, and other representational structures. This "storage system" allows new information to be predicted and learned (Bruner, 1966, p. 5).

Another principle of cognitive learning proposed by Bruner (1966) involves the increasing ability to verbalize to oneself or others, using words or symbols, what one has done or will do that creates the ability to solve problems through analytic thinking. Bruner (1960) described analytic thinking as the ability to proceed a step at a time with specific steps that can be adequately reported by the thinker to another individual.

According to cognitive theory, therefore, learning is dependent on how information is structured, organized, and conceptualized. It involves associations established according to the principles of continuity and repetition. Learning is viewed as involving the acquisition or reorganization of the cognitive structures through which humans process and store information. The items of information acquired through learning are stored, filed, and cross-indexed. This allows for meaningful learning and retention of information in an organized fashion (Good & Brophy, 1989).

Dimensional analysis is a problem-solving method that is based on the principles of cognitive theory. Hein (1983) identified that dimensional analysis provides a systematic straightforward way to set up problems and helps to organize and evaluate data that correlates with the "storage system" described by Bruner (1966). Hein also emphasized that dimensional analysis gives a clear understanding of the problem that correlates with the ability to verbalize what steps are taken leading to the type of analytic thinking as identified by Bruner (1960).

Related Literature

Although much has been written for decades about the serious problem of medication errors, the dilemma persists. As early as 1979, Perlstein, Callison, White, Barnes, and Edwards conducted a quantitative study to identify the number of errors in the drug dosage computations by personnel employed in newborn intensive care units. Five pharmacists, 11 pediatricians, and 27 nurses who worked in a newborn intensive care unit were tested for accuracy in calculating drug doses. The testing instrument was comprised of ten problems including the physician's order, the weight of the infant, and the concentration of the drug in stock. The study included only those errors that were at least 10 times greater or 10 times less than the prescribed dosage. The pharmacists received a mean test score of 96% with a range of 85% to 100%; the pediatricians received a mean test score of 89.1% with a range of 80% to 100%; and the nurses received the lowest mean test score of 75.6% with a range of 45% to 95%.

A second quantitative study, conducted by Perlstein et al. in 1979, focused only on those serious medication computational errors that might result in increased morbidity or mortality. The study included a total of 95 registered nurses (31 experienced nurses with more than one year of professional experience and 64 inexperienced nurses with less than one year of experience since graduation from nursing school). The same ten-problem testing instrument was used for this study with the 31 experienced nurses receiving a mean test score of 88.1% $\pm$ (SE) 1.7 that was not significantly different from the mean test score of 85.1% $\pm$ (SE) 1.4 received by the 64 inexperienced nurses ($p<.05$).

The researchers (Perlstein et al., 1979) concluded from the results of the studies that the most frequent computational errors involved misplacement of decimal points, careless and unclear writing that resulted in the inability to correctly identify the answer, and the lack of following ordered mechanisms of computation (figuring the problem mentally without use of a visual formula). Although hospitals have attempted to reduce medication errors by using the unit dose system, this system is not applicable for the newborn intensive care unit because doses are calculated according to weight, age, and gestation that are constantly changing variables. The study concluded that those responsible for the education of health care professionals should not assume that everyone is proficient in arithmetic skills and remedial assistance may be needed.

Dexter and Applegate (1980) found that the nursing students in an associate degree nursing program at Indiana University were having difficulty with conversions and divided dosages. They identified that the medication calculation problems encountered by students were related to a deficiency in basic mathematical skills and diverse mathematical backgrounds. They suggested that even in the face of less hands-on involvement brought on by adoption of the unit dose system, use of calculators, or preparation of intravenous medications by pharmacy, the nurse maintains legal responsibility for medication administration. They established several guidelines to improve the mathematical skills of nursing students. These guidelines included administering a mathematical quiz at the beginning of each module of the nursing program to measure and reinforce retention of previous learning; requiring 90% proficiency on mathematical quizzes consistently throughout the nursing curriculum; utilizing study guides with clear objectives and practice problems; and requesting consistency by the nursing faculty to reinforce the method of calculation (ratio-and-proportion method) that the students were originally taught. Although no statistical data were provided regarding the numbers involved in the study, the initial findings demonstrated a 5.7% increase in the dosage calculation test scores for the first group of nursing students in the new system.

Bayne and Bindler (1988) proposed fourteen questions in an exploratory study that examined whether baccalaureate prepared nurses made fewer medication errors than diploma or associate degree-prepared nurses. A twenty-item, researcher-developed medication calculation examination was administered to a sample of 62 nurses (29 registered nurses and 33 graduate nurses) obtained from two large hospitals in eastern Washington. A questionnaire was used to provide background information about the educational level of the nurses, practice settings, years of experience, and medication administration responsibilities, as well as a self-rating of overall skill in and comfort with medication calculations. The test scores ranged between 20% to 100% with 35% attaining a score of 90% or more, 54% attaining a score of 80% or more, and 75% of the nurses attaining a score of 70% or more on the test. Although an analysis of variance found that no significant correlation could be made between the scores obtained on the medication calculation exam, years of experience, level of education, or area of employment, the findings did suggest that many nurses failed to calculate correctly at the 90% level of proficiency.

Bayne and Bindler asserted that there should be great concern that many nurses lack the ability to accurately calculate medication dosages at the 90% level of proficiency. They recommended that hospitals and other health-care institutions consider periodic evaluation of the medication calculation skills of nurses similar to the type of evaluation initiated for cardiopulmonary resuscitation skills.

In a quantitative study conducted by Chenger, Conklin, Hirst, Reimer, and Watson (1988), it was revealed through use of a pretest design and background questionnaire that nursing students within the province of Alberta had difficulty in performing mathematical calculations. All of the nursing students entering and exiting each nursing program were asked to participate in the study by taking a two-part mathematical test. The mathematical test included computational and problem-solving questions. With mastery defined as a score of 90% or greater, the researchers noted that of the 210 entering students and 145 exiting students, 60% were unable to achieve mastery in problem-solving and 38.6% failed to achieve mastery in computations. They concluded that the problem was not in the students' computational abilities but in their problem-solving abilities. Their explanation for this conclusion was that problem-solving questions require cognitive as well as mathematical skills. Based on the results of the study, these investigators recommended the following: a college level math course as a prerequisite for admission into nursing programs; mathematical testing throughout the entire nursing program; remedial programs; and medication calculation mastery before clinical administration of drugs is permitted.

Worrell and Hodson (1989) conducted a random proportional sampling of 223 programs in National League for Nursing (N.L.N.) accredited baccalaureate, diploma, and associate nursing education programs to examine mathematical and dosage calculation abilities. They used a Posology Data Form (a 25-item questionnaire that examined admission requirements, student deficiencies, type of skill tested, calculation methods taught, use of calculators, types of remediation, and consequences of failure) to gather data for the study. Results revealed that 41.3% of the programs surveyed found 11-30% of their nursing students were deficient in basic mathematical skills. A Chi-square test revealed no significant relationship between educational levels and reported deficiency percentage ranges, $X2$ (2 $n=206$)$=.75$, $p<.05$.

The study conducted by Worrell and Hodson (1989) also inquired as to how students were instructed in methods of setting up a medication calculation problem. The results revealed that of 72 baccalaureate nursing programs, 48 variations of setting up the dosage calculation problem were presented. The 95 associate nursing programs involved in the study had 28 variations and the 54 diploma nursing programs had 32 variations. The results identified that the methods used differed in the labeling of the problem and use of mathematical formulas. The results focused around the multiple variations used to teach students to set up problems. The findings indicated that students may face many inconsistencies when being tutored by multiple nursing faculty members. The most noted inconsistencies identified were the labeling of problems (whether or not the problem was utilizing grains or grams) and the use of different mathematical methodologies. Several recommendations resulted from this study including requiring faculty consistency in labeling and use of mathematical formulas.

Fulton and O'Neill (1989) conducted an experimental study using a pretest/post-test design to determine the effect of mathematical anxiety on mathematical abilities. They randomly selected 80 first-year nursing students enrolled in an urban community college of nursing in Ontario. To evaluate the effects of different teaching methods on mathematical anxiety, they divided the students into control and treatment groups. They utilized a cognitive approach and taught mathematics by moving the students through a concrete phase of learning to an abstract phase of learning. T-tests revealed that there were no significant differences between anxiety scores of the two groups. They showed that variations in teaching approaches did not affect levels of anxiety or mathematical abilities. They concluded that perhaps this generation of students was not as anxious about mathematics as previous students and therefore, it should no longer be assumed that female students possess high levels of anxiety that inhibit their ability to calculate medication problems. They recommended, however, further studies of anxiety and mathematical abilities with diverse populations before conclusions can be drawn.

Bath and Blais (1993) analyzed the learning styles of 66 nursing students that were enrolled in the first-year courses in an upper-division nursing program at a large public university. Prior to their involvement in the study, all of the students had completed a course involving the calculation of drug dosage and medication administration skills. This exploratory study focused on identifying the type of learning style nursing students used to solve the medication calculation problems on a 20-item drug dosage examination. The results indicated that 83% of the nursing students used a learning style identified as the sequential, step-by-step, mathematical problem-solving method involving paper and pencil processing to solve mathematical problems. The results further indicated that only 3% of the nursing students used a learning style identified as the global, all-at-once, mathematical problem-solving method that involves mental processing to solve mathematical problems.

Bath and Blais recommended that nursing faculty members should assess the learning style of their students and develop instructional strategies to meet individual needs. Although the 3% who did use global, all-at-once mathematical problem solving strategies did obtain passing scores of 90% or greater, the study determined that a large percentage of the nursing students used sequential, step-by-step, mathematical problem-solving strategies. They further recommended that reinforcing strategies for these students would include the use of one consistent formula throughout the curriculum for solving dosage calculation problems because using more than one formula would only augment the problem with confusion.

Segatore, Edge, and Miller (1993) conducted a quantitative retrospective analysis study to identify the incidence and nature of errors in posology made by 44 sophomore nursing students in a baccalaureate nursing program. After administration of a 40-item medication computation quiz, it was determined that only 54% of the students were able to meet the pre-established passing standard of 85%. Errors were analyzed according to the type of error, including conceptual errors (identified as those involving form or set-up) and arithmetic errors (identified as incorrect addition, subtraction, multiplication, division, and use of decimals and fractions).

The results of this study indicated that 90.9% of the errors involved conceptual problems with 68.3% set-up errors (failure to provide, or inability to set up the correct formula) and 31.6% form errors (failure to provide the correct form of medication). Arithmetic errors involved only 9.9% of the errors, a phenomenon attributed to the fact that the students were allowed to use calculators. The researchers advised against assuming that nursing students have mastered mathematical skills and recommended that attention be paid to the rationale behind formulas, review of ratio-and-proportion, and demonstration of multi-step problem solving.

Gillham and Chu (1995) examined the nature of medication errors of 158 second year pre-registration nursing students in an attempt to minimize the errors. Using a pre-test design consisting of medication calculation problems and intravenous drop rate problems typically found in clinical practice, they identified that the errors fell into 10 distinct categories including basic mathematical processes, metric conversions, inaccurate approximation, and errors in formula use. Students that did not pass the first test with 100% accuracy were tested again. Division, formula use, and multiplication of fractions remained problematic errors. They concluded that the use of calculators would assist in reducing mathematical errors but the student needs to understand the cognitive effort of problem solving required for the process of dosage calculation to safely administer medications.

Pozehl (1996) revisited the issue of mathematical calculation abilities and mathematical anxiety by studying baccalaureate nursing students (n=56) and undergraduate non-nursing students (n=56) using a comparative descriptive research design. The results confirmed that nursing students had significantly lower mathematical skills than non-nursing students (only 17.9% of the nursing students passed the exam with a score of 70% or better, while 71.4% of the non-nursing students achieved a score of 70% or better). Although mathematical anxiety was higher for the nursing students than for the non-nursing students, there was no statistically significant difference in anxiety levels between the two groups. She concluded, however, that from a practical standpoint, nurse educators can not disregard the debilitating effects of mathematical anxiety. She recommended that nurse educators create a learning environment that will help students obtain a positive attitude regarding mathematics by exploring methods of instruction that will decrease anxiety.

Lussier (1996) examined the relationship between sex and background in mathematics (classification variables) with measures of anxiety and self-efficacy in mathematics (dependent variables) using an *ex post facto* 2 x 2 factorial design. This study, conducted at a private liberal arts college in the Pacific northwest, concluded that students with more years of mathematical background experienced significantly lower mathematical anxiety than those students with less years of mathematical background. There were no sex differences related to mathematical background and levels of anxiety. This study contradicted the results of the study by Betz (1978) who identified that females have higher levels of mathematical anxiety.

Ashby (1997) conducted an exploratory study to assess the medication calculation abilities of nurses practicing on medical-surgical floors in the acute care setting. The sample size included 62 practicing medical-surgical nurses from a 380 bed hospital located in the Midwest (31 [50%] of the nurses held baccalaureate degrees, 23 [37%] associate degrees, and 8 [13%] diploma degrees). The medication calculation abilities of the nurses were evaluated using the 20-item Bayne-Bindler Medication Calculation Test (1988). The results of the medication test revealed that 35 nurses (56.4%) lacked the ability to calculate medication problems correctly in 90% of the problems. It also was established that educational preparation was not significantly related to medication errors which should be a major concern for nurse educators at all levels of nursing education.

Additionally, Ashby (1997) explored the relationship between medication administration and stress levels. She found that 57% of the nurses practicing on medical-surgical floors reported that medication calculation and administration was a task that produced stress.

Using quantitative research studies, the nursing literature examined the reasons for the medication calculation deficiencies among nurses and nursing students. The chemistry literature, however, focused on studies analyzing the use of different formulas for solving mathematical equations. Although there is a paucity of information within the chemistry literature analyzing different formulas, the chemistry literature has researched dimensional analysis as a problem-solving method for reducing mathematical deficiencies.

In a post-test only control group design, Gabel and Sherwood (1983) conducted a study of 609 randomly selected high school chemistry students in central and south-central Indiana to determine whether certain types of instructional strategies were superior to others when teaching problem solving in chemistry courses. The strategies included proportionality, analogies, diagrams, and factor-label method (also known as dimensional analysis). The factor-label method (dimensional analysis) was demonstrated to be the most desirable method for teaching the mole concept. As defined by the American Heritage dictionary (1992) a mole is the amount of a substance that contains as many atoms, molecules, ions, or other elementary units as the number of atoms in 0.012 kilogram of carbon 12. The mole concept can be correlated with the type of medication calculation problems that nursing students or nurses face daily in the clinical setting (converting grams to grains or grams to milligrams) because both concepts are abstract and require conversions to solve the problem.

Bunce and Heikkinen (1986) investigated the effects of teaching an explicit problem-solving approach on the mathematical chemistry achievement of preparatory college students. Introductory chemistry students (n=200) were randomly assigned to a control group (receiving instruction with the explicit problem solving approach) and an experimental group (receiving instruction with the problem-solving strategy of dimensional analysis). The results of the study did not demonstrate a statistically significant difference ($F=2.05$, $p=.092$) with the problem solving approaches, although the trend was toward improved performance with the students taught dimensional analysis. The study did not elaborate on dimensional analysis as a problem-solving method.

Hauben and Lehman (1988) conducted a study using a post-test only control group design that examined a computer assisted instruction (CAI) module on problem solving with dimensional analysis. The study involved 57 chemistry students that were randomly assigned to a treatment group (28 used the CAI module on dimensional analysis) and a control group (29 used a paper and pencil version). The content for the experimental group (CAI) and the control group (paper/pencil modules) was the same. Both groups were previously exposed to the problem-solving method of dimensional analysis and were familiar with measurements required for conversions.

The means and standard deviations of the post-test scores were analyzed and proved to be significant at the .05 alpha level. The experimental group (CAI) was significantly superior ($p=<.05$) to the control group (paper/pencil) on both volume and word problems but not mass and length. The students in both groups also were asked to rate their attitudes regarding dimensional analysis as a problem-solving method and both groups were very positive in their ratings of dimensional analysis, with the experimental group (CAI) significantly more positive ($p=<.001$) about the use of dimensional analysis than the control group.

One quantitative study was found in the nursing literature that evaluated the effects of dimensional analysis on the medication dosage calculation abilities of nursing students (Craig & Sellers, 1995). This quasi-experimental study examined whether the use of dimensional analysis would improve the medication dosage calculation abilities of nursing students. The convenience sample ($n=59$) included an experimental group of 30 nursing students enrolled in the second year of a diploma nursing program and 29 nursing students enrolled in the second year of an associate degree nursing program. Using a pretest/post-test design, students in the experimental group were instructed using dimensional analysis as a problem-solving method and students in the control group were instructed using the problem-solving methods of ratio-and-proportion or desired dose/dose on-hand. It was found using an independent t-test that the students in the experimental group had a statistically significant improvement between the pretest/post-test scores ($p=.00001$). Although the post-test scores of the experimental group were not significantly higher than the control group statistically ($p=.78$), the improvement in the post-test scores of the experimental group warrants further research in the use of dimensional analysis as a problem-solving method.

Summary

A number of studies from the nursing literature have identified that medication errors involving inadequate medication calculation abilities of nurses and nursing students remain an ongoing problem. The investigators focused on several reasons for the medication calculation deficiencies of nurses and nursing students.

Several studies identified the lack of mathematical skills as the reason for medication errors and introduced remediation with self-learning packets (Bayne & Bindler, 1988; Dexter & Applegate, 1980; Ptaszynski & Silver, 1981). Other studies revealed that the problem of medication errors was not only mathematical but conceptual as well and recommended further study (Blais & Bath, 1992; Chenger et al., 1988). One study concluded incorrect labeling of the problem and inconsistencies with teaching different formulas contributed significantly to medication errors (Worrell & Hodson, 1989). Other studies identified the problem of medication errors involved the inability of the student to conceptualize and set up the problem correctly (Blais & Bath, 1992; Segatore, Edge, & Miller, 1993). Additionally, it was concluded the learning style of each student needs to be analyzed because the majority of nursing students utilized a step-by-step process that required conceptualization of the problem (Bath & Blais, 1993). Finally, it was suggested that mathematical anxiety be reduced by utilizing a desensitization program or a method that will provide a positive learning environment (Hendel & Davis, 1978; Pozehl, 1996).

The chemistry literature suggested dimensional analysis as a problem-solving method that can be applied to the teaching of medication dosage calculation (Bunce & Heikkinen, 1986; Gabel & Sherwood, 1983). Dimensional analysis was shown to be effective with mole conversions that are conceptually similar to the types of medication calculation problems that nurses and nursing students encounter in clinical nursing practice. Dimensional analysis is based on cognitive theory that allows conceptualization of the medication calculation problem utilizing a problem-solving method that follows a step-by-step process.

Craig and Sellers (1995) researched dimensional analysis and found it significantly improved the medication calculation abilities of nursing students. Numerous quantitative studies have identified that medication errors are related to mathematical, conceptual, and cognitive deficiencies. Although quantitative studies can provide statistical data on the effectiveness of a problem-solving method, qualitative research studies provide thick, rich descriptions to assist in understanding the mechanisms that underlie the intervention by exploring how and why a particular problem-solving method is effective. No qualitative research was found regarding the effectiveness of dimensional analysis in the nursing literature. A qualitative study, however, could provide new information on understanding the concepts involved in learning dimensional analysis as a problem-solving method for medication calculation, an area yet to be explored. Therefore, the question that must be answered is "What perceptions do nursing students have regarding the effectiveness of dimensional analysis as a problem-solving method for medication calculations?"

Chapter 3
METHODOLOGY

The purpose of this study was to explore the perceptions of nursing students regarding the effectiveness of dimensional analysis as a problem-solving method for medication calculations. Specifically, the study answered the grand-tour question, "What perceptions do nursing students have regarding the effectiveness of dimensional analysis as a problem-solving method for medication calculations?" Based on the nursing literature regarding mathematical, conceptual, and cognitive deficiencies and mathematical anxiety levels of nurses and nursing students, four sub-questions also were included:

1. What perceptions do nursing students have regarding dimensional analysis and their mathematical calculation abilities?
2. What perceptions do nursing students have regarding dimensional analysis and their conceptual abilities?
3. What perceptions do nursing students have regarding dimensional analysis and their cognitive abilities?
4. What perceptions do nursing students have regarding dimensional analysis and their anxiety levels?

Answers to these questions assisted in providing insight and understanding as to whether or not dimensional analysis was an effective problem-solving method for medication calculations from the nursing student perspective. The purpose of this qualitative research study was to increase knowledge regarding the intervention of dimensional analysis and understand the mechanisms (interrelated parts) that underlie dimensional analysis from the student perspective. Dimensional analysis has been identified as an effective method for solving mathematical problems that require some type of conversion. To assist students who are having difficulty with medication calculations, it was important to understand how and why dimensional analysis works for these students so that it can successfully be used with other students. Additionally, answers to these questions provided insight into whether or not dimensional analysis improved the mathematical, conceptual, and cognitive abilities of nursing students and decreased anxiety levels.

This chapter focuses on the research methodology used for the study and includes the following sections: research design, sample and sampling plan, data collection instruments, data collection procedures, and protection of human subjects. A brief summary concludes the chapter.

Research Design

The design for this study was a qualitative evaluation research design. This design provided thick, rich descriptions regarding the effectiveness of dimensional analysis as a problem-solving method for medication calculations from the perspective of nursing students. To improve the credibility of the findings from this qualitative study, triangulation was obtained through the use of multiple referents (Lincoln & Guba, 1985). Triangulation was achieved through the use of participant observation, one-to-one, open-ended interviews, and a closed-ended questionnaire. Data obtained from the nursing students provided themes and conceptual patterns regarding the effectiveness of dimensional analysis as a problem-solving method for medication calculations.

Sample and Sampling Plan

A purposeful sampling plan was utilized with nursing students enrolled in a three-year diploma nursing education program from a hospital-based school of nursing located in central Iowa. The original size of the sample included 33 nursing students. Four of the nursing students withdrew from the diploma nursing program for various reasons following the first semester and two students chose to use ratio-and-proportion as a problem-solving method reducing the sample to 27 nursing students.

After approval was obtained from the School of Nursing (9-17-96) and Drake University Human Subjects Research Review Committee (7-19-97), students enrolled in a first year introductory basic nursing course (Nursing 130) were invited to participate in the study that would extend over three semesters. Conducting the study over three semesters enhanced the credibility of the study through use of prolonged engagement to provide scope and persistent observation to provide depth (Lincoln & Guba, 1985). To promote confidentiality and data security, the participants in the study were asked to utilize the last four digits of their social security number to allow matching of the data obtained from the study.

Data Collection Instruments

To assist with measuring demographic factors that described the sample, a demographic collection tool (Appendix A) was administered to all subjects to obtain the following data: age, sex, how recently the student had completed a course in introductory chemistry in a community college or university, how many years of high school mathematics were completed, and the level of anxiety regarding mathematics.

Determining whether or not students had completed a course in introductory chemistry was considered an important piece of information because students may have already established positive or negative perceptions regarding dimensional analysis prior to participation in this study. Information regarding the number of years of high school mathematics also was considered important to the study to assist in clarifying perceptions regarding previous mathematical abilities or anxiety.

A researcher-developed, closed-ended questionnaire (Appendix D) consisting of 20 questions was administered to the subjects to obtain information regarding the effectiveness of dimensional analysis, the teaching strategy used in the study, and the learning environment created for the study. The first four questions on the questionnaire were the four mini-tour questions used in the one-to-one open-ended interviews. These questions were included on the questionnaire to receive input from all the students participating in the study regarding their perceptions of dimensional analysis and their mathematical, conceptual, and cognitive abilities and anxiety levels.

The textbook entitled *Clinical Calculations using Dimensional Analysis* (Craig, 1997) was used to provide the foundation for teaching dimensional analysis to the nursing students in the study. Questions regarding the content, examples, and illustrations used in the textbook also were included on the questionnaire to provide feedback regarding the simple to complex, step-by-step approach used to teach dimensional analysis. These questions were included on the questionnaire to evaluate whether the teaching strategy used during the research utilizing the textbook was based on cognitive learning theory (Bruner, 1960; 1966).

An additional question was included that addressed the use of music, color, and peripheral learning charts to maximize and promote learning in a positive environment. This question was included on the questionnaire in an effort to evaluate if the learning environment used during the study decreased anxiety through desensitization and promoted positive attitudes toward mathematics (Hendel & Davis, 1978; Pozehl, 1996).

Credibility and dependability of both instruments were established through examination by two faculty members and the major advisor of the study. One faculty member had a master's degree in nursing and the other a master's degree in adult education. Both were familiar with dimensional analysis.

Data Collection Procedures

The participants in the study were verbally informed about the study by the researcher. A cover letter (Appendix B) and a student informed consent form (Appendix C) were utilized by the researcher to convey information to the nursing students.

The nursing students received four hours of didactic education in Nursing 130. Nursing 130 is a first year introductory basic nursing course in which students begin administration of simple oral medications (one-factor medication problems). Two hours of didactic education were offered to the nursing students in Nursing 230. Nursing 230 is a second year medical-surgical nursing course in which students begin administration of subcutaneous medications, intramuscular medications, and intravenous fluids (two-factor medication problems). Nursing students in Nursing 330 also received two hours of didactic education. Nursing 330 is a third year family adaptation nursing course in which students have the responsibility of administering more complex medications including intravenous medications (multi-step problems and three-factor medication problems).

Dimensional analysis was taught using the teaching strategy as outlined in the textbook entitled *Clinical Calculations using Dimensional Analysis* (Craig, 1997). Throughout the three semesters, reinforcement and periodic evaluation was maintained through inclusion of three medication calculation problems on randomly chosen exams to maintain continuity and stimulate involvement but these scores were not calculated as part of the grade point for course grades.

Participant observation was obtained by placing videotaping equipment in the front of the classroom to observe for the non-verbal reactions of anxiety and confusion from the nursing students during the didactic presentation. Anxiety and confusion were chosen as concepts based on the nursing literature and to correlate with the mini-tour question regarding dimensional analysis and anxiety levels. A trained observer was positioned in the back of the classroom to observe for student interaction and attentiveness during the didactic presentations. Student interaction and attentiveness were chosen as concepts based on the literature regarding conceptual and cognitive difficulties and to correlate with the mini-tour questions. The trained observer was familiar with dimensional analysis and had an educational background in research and statistics at the baccalaureate level. The observer was trained by the researcher to look for student interactions and signs of attentiveness (keeping on task), anxiety (restlessness), or confusion (side discussions or questions).

Students requesting additional tutoring because of difficulty working in large groups and mathematical anxiety were invited to participate in one-to-one, open-ended interviews using the four mini-tour questions at the conclusion of the program. These students were chosen based on the criteria for sampling of critical cases. Sampling critical cases permits maximum application of information because if the information is valid for critical cases, it is likely to be true in all other cases (Lincoln & Guba, 1985). This type of sampling provides an opportunity to learn from the most unusual and extreme subjects like nursing students who have had difficulty calculating medication problems related to mathphobia (Polit & Hungler, 1997). The one-to-one, open-ended interviews were conducted at the conclusion of the three semester study using a video camera to obtain verbal and non-verbal data. Each interview was transcribed, coded, and compared to the transcription following the steps used for constant comparative data processing (Lincoln & Guba, 1985). The raw units of information obtained from the one-to-one, open-ended interviews were inductively analyzed by unitizing each unit of information on 4 x 6 index cards, categorizing the units of information, identifying emerging themes (recurring regularities) within the categories, and finally placing the themes into conceptual patterns (Lincoln & Guba, 1985; Miles & Huberman, 1994; Polit & Hungler, 1997).

All students were asked to complete a closed-ended questionnaire (Appendix D) to obtain additional information regarding the perceptions of the nursing students about the effectiveness of dimensional analysis utilizing the four sub-questions. To evaluate the teaching strategy used throughout the research, students also were asked to provide feedback about the content, examples, and illustrations used from the textbook entitled

Clinical Calculations using Dimensional Analysis (Craig, 1997). Additionally, as a means of addressing desensitization and promotion of positive attitude, students were asked to address whether or not the use of music, color, and peripheral learning charts maximized their learning by creating a positive learning environment.

Protection of Human Subjects

Permission to conduct the study was obtained from the School of Nursing (9-17-96) and Drake University Human Subjects Research Review Committee (7-19-97). The rights of subjects, including the right to freedom from harm, the right to informed consent, and the right to privacy, were maintained throughout the study. A cover letter (Appendix B) and a student consent form (Appendix C) were given to each participant. The cover letter included the purpose of the study, the procedures that would be followed, the benefits of participation, the risks of participation, and how the results of the study may be obtained. The participants also were informed that their participation in the study would not affect their student status or grade point. All names were kept confidential and reported in aggregate. Information obtained from the study was kept in a locked file and destroyed at the completion of the study.

Summary

To explore the perceptions of nursing students regarding the effectiveness of dimensional analysis as a problem-solving method, a qualitative research study was designed. The study included 27 nursing students enrolled in a three-year diploma nursing education program from a hospital-based school of nursing located in central Iowa. Two data collection instruments were used for the study. To assist with measuring demographic factors that described the sample, a demographic data collection instrument (Appendix A) was administered to all participants. To assist with obtaining information about the perceptions of the nursing students regarding the effectiveness of dimensional analysis, the nursing students were asked to complete a closed-ended questionnaire (Appendix D). Triangulation of the data was obtained through participant observation, one-to-one open-ended interviews, and a researcher-developed, closed-ended questionnaire. Chapter 4 analyzes the data obtained from this qualitative study.

Chapter 4
ANALYSIS OF DATA

The purpose of this qualitative study was to answer the question, "What perceptions do nursing students have regarding the effectiveness of dimensional analysis as a problem-solving method for medication calculations?" Based upon the information provided in the literature regarding mathematical, conceptual, and cognitive deficiencies and mathematical anxiety, four sub-questions also were researched:

1. What perceptions do nursing students have regarding dimensional analysis and their mathematical calculation abilities?
2. What perceptions do nursing students have regarding dimensional analysis and their conceptual abilities?
3. What perceptions do nursing students have regarding dimensional analysis and their cognitive abilities?
4. What perceptions do nursing students have regarding dimensional analysis and their anxiety levels?

This chapter is divided into three sections. The first section describes the demographic characteristics of the sample. To address the research questions, the second section analyzes the information obtained through participant observation, one-to-one, open-ended interviews, and the closed-ended questionnaires. The final section summarizes the chapter.

Description of the Sample

The sample consisted of 27 nursing students enrolled in a three-year diploma nursing program located in central Iowa. As indicated by Table 1, of the 27 nursing students, 18 students (66.67%) were between the ages of 18 and 22, three students (11.11%) were between the ages of 23 and 27, three students (11.11%) were between the ages of 28 and 35, and three students (11.11%) were 36 years of age or older. The subjects included two male nursing students (7.41%) and 25 female nursing students (92.59%). Four nursing students (14.81%) had completed an introductory chemistry course in a community college or university within the last two years, four students (14.81%) had completed a course within the last three to five years, and 19 students (70.38%) had never enrolled in an introductory chemistry course as part of post-secondary education. One nursing student (3.71%) had completed only one year of high school mathematics, one student (3.71%) had completed two years, 15 students (55.55%) had completed three years, four students (14.81%) had completed four years, and six students (22.22%) had completed four years of high school mathematics plus post-secondary education. None of the nursing students identified themselves as having no anxiety when solving mathematical problems, nine students (33.33%) had mild anxiety, 15 students (55.56%) had moderate anxiety, and three students (11.11%) confirmed that they have severe anxiety when solving mathematical problems. Table 1 summarizes the demographics by characteristics, number, and percentages.

Table 1

Summary of Demographic Characteristics of the Sample

CHARACTERISTICS	NUMBER (N)	PERCENTAGE (%)
AGE		
18-22	18	66.67
23-27	3	11.11
28-35	3	11.11
36 and above	3	11.11
TOTAL	27	100.00
SEX		
Male	2	7.41
Female	25	92.59
TOTAL	27	100.00
CHEMISTRY		
Last 2 Years	4	14.81
Last 3-5 Years	4	14.81
Last 6-10 Years	0	0.00
More than 10 Years	0	0.00
Never	19	70.38
TOTAL	27	100.00
HIGH SCHOOL MATHEMATICS		
1 Year	1	3.71
2 Years	1	3.71
3 Years	15	55.55
4 Years	4	14.81
4 Years Plus	6	22.22
TOTAL	27	100.00
ANXIETY		
No Anxiety	0	0.00
Mild Anxiety	9	33.33
Moderate Anxiety	15	55.56
Severe Anxiety	3	11.11
TOTAL	27	100.00

Analysis of Information

The grand-tour question researched for this study was: "What perceptions do nursing students have regarding the effectiveness of dimensional analysis as a problem-solving method for medication calculations?" Based on the nursing literature four sub-questions also were researched:

1. What perceptions do nursing students have regarding dimensional analysis and their mathematical calculation abilities?
2. What perceptions do nursing students have regarding dimensional analysis and their conceptual abilities?
3. What perceptions do nursing students have regarding dimensional analysis and their cognitive abilities?
4. What perceptions do nursing students have regarding dimensional analysis and their anxiety levels?

Participant Observation

To obtain information regarding the non-verbal reactions of anxiety and confusion, videotaping equipment was placed in the front of the classroom. To observe for student interaction and attentiveness, a trained observer was positioned in the back of the classroom. Dimensional analysis was taught all three semesters using teaching strategies outlined in the textbook entitled *Clinical Calculations using Dimensional Analysis* (Craig, 1997). The teaching strategies obtained from the textbook were augmented through the use of Microsoft Powerpoint presentations and handouts obtained from the textbook.

The nursing students were offered four hours of didactic education in Nursing 130 (a first year introductory nursing course which included simple, one-factor medication problems). To enhance the learning process and promote a positive learning environment during these presentations, classical music was softly played in the background and colorful, peripheral learning charts of the unit path and conversions were displayed on the walls. To increase hands-on participation, each student received a packet with samples of an oral medication cup and an oral syringe and three different types of injection syringes (an insulin syringe, a tuberculin syringe, and a 3 cc syringe). Other visual examples of measurements (a half-liter and liter container, a half-gallon and gallon container, and numerous stock bottles of medications) were displayed on a table in the middle of the classroom.

Due to a conflict in the scheduling, the didactic presentation was offered twice to the students in Nursing 130. Six students attended the first N130 presentation and 20 students attended the second presentation. Both of these presentations were videotaped. Following these presentations the students requested a practice session intended solely for solving additional medication problems provided by the researcher. This session was attended by 20 students but was not video-taped as part of the research. Following the didactic presentation and practice session, two students continued to experience difficulty with medication calculations and requested and received additional one-to-one tutoring following the N130 presentations. The two students (who expressed difficulty learning in large groups related to mathphobia) were identified as critical cases for sampling. Table 2 displays the information obtained from the participant observations and Table 3 displays the information obtained from the videotaping of the presentations.

Table 2

<u>N130 Participant Observation Data</u>

N130 Participant Observation	Examples
Anxiety	One student was continuously bouncing her foot through most of the presentation.
Confusion	One student was continuously looking at the paper of the student next to her. Numerous side discussions were observed. Several students began raising their hands and asking questions of the presenter.
Student Interaction	Several older students sat quietly, worked alone, and did not engage in conversation with students around them. Students appeared interested in the hands-on materials (medication bottles, syringes, and cups). During the practice time for "Arithmetic Review" and "Common Equivalents," students worked independently. During the practice time for "Solving Problems with DA" and "One-Factor Medication Problems," students began working together and comparing notes. Several students openly demonstrated excitement when the correct answer was discovered. During the final practice time for "Solving Problems with DA," several students volunteered to place their answers on the blackboard. Several students worked completely on their own during the practice times.
Attentiveness	The students followed along with the Powerpoint screen presentation and handouts. The students appeared relaxed (sat looking forward and occasionally rested their head on their hands).

Table 3

N130 Video Observation Data

N130 Video Observation	Examples
Anxiety	One student was constantly bouncing her foot.
Confusion	No non-verbal signs of confusion were observed. Numerous side discussions were observed. Students raised their hands and asked questions
Student Interaction	Several students sat quietly and did not interact with the students sitting next to them or turn the pages of their handouts at the same time as the other students. Other students interacted with each other and shared examples from their papers.
Attentiveness	Students appeared attentive demonstrated by occasional smiles and nodding heads. Students followed along with the presentation turning the pages at the appropriate times. Three students on the left side of room volunteered to solve problems on the blackboard. One student on the right side of the room volunteered to solve a problem on the blackboard.

Two hours of didactic education was offered to the nursing students in Nursing 230 (a second year medical-surgical nursing course which included more complex two-factor medication problems). Nineteen students attended this presentation. In an effort to address desensitization and promote a positive environment, enhancement of the learning process was augmented through the use of background, classical music and colorful, peripheral learning charts displayed on the walls in the classroom. Hands-on participation was encouraged through the use of student packets with samples including an oral medication cup and an oral syringe and three different types of injection syringes (an insulin syringe, a tuberculin syringe, and a 3 cc syringe) as well as examples of medication vials for reconstitution. Other visual examples displayed in the middle of the classroom included intravenous solutions (50, 100, 250, 500, and 1000 cc bags), an IV pump with attached IV bag and tubing, and an IV pole with attached bag and tubing.

Two students requested and received additional one-to-one tutoring following the N230 presentations because they were having difficulty solving the medication problems in the large group setting. Both of these students also received additional one-to-one tutoring following N130. Table 4 displays the information obtained from the participant observations and Table 5 displays the information obtained from the videotaping of the presentations.

Table 4

N230 Participant Observation Data

N230 Participant Observation	Examples
Anxiety	No signs of anxiety were noted
Confusion	Several side discussions were observed.
Student Interaction	Students worked independently to find answers to the problems and then compared answers with other students.
Attentiveness	Only a few students answered questions during the first part of the presentation. Students appeared interested and attentive especially when solving problems that involved working with the medication vials to find the solution to the problem. Several students left early.

Table 5

N230 Video Observation Data

N230 Video Observation	Examples
Anxiety	No non-verbal signs of anxiety were observed.
Confusion	No non-verbal signs of confusion were observed. Several side discussions were observed.
Student Interaction	Students were sharing medication vials and comparing hand-outs. One student sat alone and worked problems independently.
Attentiveness	Students verbally participated by answering questions. Several students volunteered to solve problems on the blackboard. Students were smiling and joking with each other and the presenter. Several students were more boisterous than the other students. Several students left early.

Two hours of didactic education was offered in Nursing 330 (a third year family adaptation nursing course which included multi-step medication problems and complex three-factor medication problems). Twenty-nine nursing students attended this didactic presentation (two nursing students not involved in the study attended the presentation to practice problems with the ratio-and-proportion method). Desensitization and a positive learning environment were enhanced with background classical music and colorful, peripheral learning charts. To promote student involvement and participation, each student received a packet with samples of an oral medication cup and an oral syringe and three different types of injection syringes (an insulin syringe, a tuberculin syringe, and a 3 cc syringe) as well as numerous examples of medication vials for reconstitution. Other visual examples displayed in the middle of the classroom included intravenous solutions (50, 100, 250, 500, and 1000 cc bags), an IV pump with attached IV primary and secondary bags and tubing, and an IV pole with attached primary and secondary bags and tubing. Six students received additional one-to-one tutoring following N330 presentations. Two of these students had received additional one-to-one tutoring following N130 and N230 and the other four students requested one-to-one tutoring following N330 due to the complexity of the medication calculation problems. Table 6 displays the information obtained from the participant observations and Table 7 displays the information obtained from the videotaping of the presentations.

Table 6

N330 Participant Observation Data

N330 Participant Observation	Examples
Anxiety	No displays of anxiety were observed.
Confusion	Numerous side discussions were observed. Students started asking questions after the second problem was presented.
Student Interaction	Students helped other students (shared medication vials and drug books). Several students worked independently. Students solved problems and them compared papers with the student next to them.
Attentiveness	Students laughed after the presentation of the first complex problem. Students appeared interested and were looking at the hand-outs and medication vials. Students followed along with the step-by-step process of solving the complex problems (turning pages at the appropriate times). One student identified an error on the blackboard made by the presenter. After one hour, students began looking at the clock.

Table 7

N330 Video Observation Data

N330 Video Observation	Examples
Anxiety	No non-verbal displays of anxiety were observed.
Confusion	Puzzled looks and side-glances were observed after presentation of the first problem. Several students were shaking their heads. Numerous side discussions were observed.
Student Interaction	Students worked in pairs or groups when solving problems and sharing medication vials. Students nodding heads and smiling at each other. Students were looking at each others papers and marking on each others papers.
Attentiveness	Several students arrived late. Students followed along with hand-outs. Students worked problems and answered questions. Students checked answers with the presenter and then placed the problem on the blackboard.

Open-ended Interviews

To provide insight and understanding as to whether or not dimensional analysis was an effective problem-solving method for medication calculations from the student perspective, six students (critical case sampling) requesting additional one-to-one tutoring were invited to participate in one-to-one open-ended interviews at the conclusion of the program, utilizing the grand-tour question and the four sub-questions.

The students interviewed were videotaped to obtain the verbal and non-verbal reactions from the students. Each interview was approximately 30 to 60 minutes in length. Each videotape was coded, transcribed, and compared to the transcription following the steps for data processing as identified by Lincoln and Guba (1985).

The researcher and trained observer analyzed the transcripts and discussed the responses obtained from the nursing students independent of the auditor. The raw units of information obtained from the grand-tour question and sub-questions during the interviews were inductively analyzed by unitizing each unit of information on 4 x 6 index cards, categorizing the units of information according to the questions, identifying emerging themes (recurring regularities), and finally placing the themes into conceptual patterns.

The external peer reviewer audited the information by analyzing the data examples on the index cards, identifying key themes from each card, writing the themes on easel paper, and categorizing the themes into conceptual patterns. Following the analysis by the auditor, the themes and conceptual patterns were compared for consistency. Regardless of whether the grand-tour question and sub-questions were unitized and categorized or whether the statements independent of the questions were unitized and categorized, the themes and conceptual patterns identified remained consistent. Students used similar language to express their perceptions thus the themes and conceptual patterns that emerged from the interviews were consistent, adding greater significance to the findings.

The six students interviewed all agreed that dimensional analysis was an effective problem-solving method for medication calculation problems. Table 8 displays the perceptions of the students regarding the effectiveness of dimensional analysis as a problem-solving method.

Table 8

Student Perceptions Regarding the Effectiveness of Dimensional Analysis

Interviewee	Data Examples
Interviewee #1	It's almost like I feel safe with DA. When I first started nursing school I didn't have any math ability behind me at all. When I started using DA it kind of made a lightbulb go off and I understood finally the meaning behind the math and before I never understood how to go about it.
Interviewee #2	Well, I know that even when I take my little cheat sheet with me, which I will do for a long time, no matter what problem I'm hit with in nursing, I will have the formula there to solve it. So that takes a lot of burden off me.
Interviewee #3	I think that DA makes things more clear, that I was able to think through problems and see them more clearly. I took things step-by-step and gradually developed the answer by using DA. It helped me tremendously, before I was never quite sure how to set up a problem. And using DA I could do it.
Interviewee #4	I had a terrible time with algebra and figuring out how to think things through. It was very trying to try to remember how to do things. But the way that you went through showing us how to set up problems step-by-step with DA was very helpful. I think it is a very nice way to problem solve. I feel it has been very effective for me.
Interviewee #5	I think DA is very effective just for the fact that I was never good in math. But you went through a couple of problems with us and I almost caught on just like that (snapping fingers). It was very effective for me in that manner because it was easy in the way that it was set up.
Interviewee #6	I would say for me that knowing that I am on the right track and canceling out for me is a real effective way because I can tell if I'm not on the right track or what I need to do next or what I haven't done yet.

Based on the data examples provided from the perceptions of the nursing students, three conceptual patterns were identified:

1. Lack of Mathematical Abilities
2. Comprehension
3. Positive Feelings

The conceptual pattern "lack of mathematical abilities" was supported by four consistent themes obtained from the data examples. The first theme from this pattern involved identification of negative feelings regarding mathematics expressed by the nursing students. The second emerging theme identified the fact that several of the students were adult learners that had been out of school for many years and had forgotten their mathematical skills. The third theme from this pattern identified that several of the students had limited mathematical backgrounds. The final theme expressed by the students was that several students considered themselves better in the arts and sciences and had never been able to understand mathematics. Typically the type of student more interested in the arts is considered a right-brain learner and the type of student more interested in mathematics is considered a left-brain learner. Further discussion of this concept will be presented in Chapter 5.

The conceptual pattern "comprehension" was supported by two consistent themes obtained from the perceptions of students regarding dimensional analysis and their conceptual and cognitive abilities. The themes obtained from the students for this pattern were somewhat synergistic in that the reason the students understood how to solve a problem with dimensional analysis involved the ability to visualize the problem-solving method and follow logical steps to solve the problem that ultimately allowed for a recheck of an answer for accurateness.

The remaining emerging themes expressed by the students involved confidence, reduced anxiety, and reduced stress. These themes were placed in the conceptual pattern "positive feelings."

Table 9 displays the examples of significant statements obtained from the perceptions described by the nursing students. The table is divided into data examples, and the abstractions from the statements made by the students into themes, and finally into the three conceptual patterns.

Table 9

Data Examples, Themes, and Conceptual Patterns from Open-ended Interviews

Data Examples	Themes	Conceptual Patterns
I can't do math, I never have been able to do math, I never had any confidence.	Negative Feelings	Lack of Mathematical Abilities
I was just never any good at math. I didn't have any abilities therefore I was stupid and my whole life I was labeled as stupid.	Negative Feelings	Lack of Mathematical Abilities
I used to think that when I did math problems there was something wrong with the way I thought. I felt like I was the only one in the class not getting it so there was something wrong with me because I am too dumb or I'm stupid.	Negative Feelings	Lack of Mathematical Abilities

Table 9 (Continued)

Data Examples, Themes, and Conceptual Patterns from Open-ended Interviews

Data Examples	Themes	Conceptual Patterns
I had a lot of problems with math. I used to not want to go to school, it was kind of a problem for me my whole life, math was just a big barrier, a huge barrier.	Negative Feelings	Lack of Mathematical Abilities
I used to freak out when it came to math. I didn't want to go anywhere near it. I used to think I was stupid when it came to math. It was just too hard for me.	Negative Feelings	Lack of Mathematical Abilities
It is still ingrained in me and I still have a tendency when anything mathematical comes up to just panic and hyperventilate and totally lose my mind.	Negative Feelings	Lack of Mathematical Abilities
I was scared, I was really, really frightened. Usually when you go to a math class they assume that you know this, they assume that you are a "normal person" (making carrots around the spoken word).	Negative Feelings	Lack of Mathematical Abilities
Math came so hard for me that I never really grasped anything. With me there was no hope in math.	Negative Feelings	Lack of Mathematical Abilities
It has been such a long time since I've had any math as far as school goes.	Adult Learner	Lack of Mathematical Abilities

Table 9 (Continued)

Data Examples, Themes, and Conceptual Patterns from Open-ended Interviews

Data Examples	Themes	Conceptual Patterns
When I was in high school math came easy to me (algebra and geometry) but that was 15 years ago and if you don't use it, you lose it.	Adult Learner	Lack of Mathematical Abilities
I used to be good at math when I was younger but now that I'm older I think that I have lost the math cells in my brain.	Adult Learner	Lack of Mathematical Abilities
Math has never been emphasized in my life.	Limited Mathematical Background	Lack of Mathematical Abilities
I didn't have very strong math abilities. I was never very good in math.	Limited Mathematical Background	Lack of Mathematical Abilities
I didn't have any math ability behind me at all. And when I first started doing math calculations I failed almost every test that we had.	Limited Mathematical Background	Lack of Mathematical Abilities
I had algebra and geometry and geometry was the hardest and I got so I could just pass the algebra class.	Limited Mathematical Background	Lack of Mathematical Abilities
It was just math that I had a hard time with, my favorites were reading and English. I loved art and music.	Right-Brain Learner	Lack of Mathematical Abilities
Math was never a good subject with me. I liked interior design and learning about the different stages that people go through. I started out in school in interior design.	Right-Brain Learner	Lack of Mathematical Abilities

Table 9 (Continued)

Data Examples, Themes, and Conceptual Patterns from Open-ended Interviews

Data Examples	Themes	Conceptual Patterns
If I can see something laid out a certain way it helps me. I could never do math because it was going down this way (moving hands vertically). I could never do that but when it is laid out in front of me (moving hands horizontally) it is almost like reading a book. It is easier for me to follow, something clicks in my brain laid out that way and I can see the math problem better.	Right-Brain Learner	Lack of Mathematical Abilities
I was the one who liked to paint, to draw, to write poetry.	Right-Brain Learner	Lack of Mathematical Abilities
I love music and art but I don't like math. I listen to music all the time and I write lyrics.	Right-Brain Learner	Lack of Mathematical Abilities
I finally understood what I was doing because I actually could see what I was doing. So that helped me a lot.	Visualization	Comprehension
The first thing I see is the unit path, that is the first thing I see and it helps me laid out that way.	Visualization	Comprehension
The unit path is a picture that I put on paper and it comes to me. And you go left to right just like I read.	Visualization	Comprehension

Table 9 (Continued)

Data Examples, Themes, and Conceptual Patterns from Open-ended Interviews

Data Examples	Themes	Conceptual Patterns
But when it was set up in the DA manner I said I actually can see this, I can get this, this is wonderful.	Visualization	Comprehension
Things have to be a picture for me, that is how I see it. When I am studying and I don't understand something I take my son's crayons out and make a picture of it. I have to picture things in my head and if I can picture it, I can remember it.	Visualization	Comprehension
But with DA, it was set up in a way that I knew I could think about it, I could look at the problem, I could think.	Visualization	Comprehension
With DA the set up is very logical. When I am reading the problem I can picture in my mind where it is supposed to go. I always start off with the unit path line.	Visualization	Comprehension
I start off by identifying my wanted quantity then my given quantity and then all my conversion factors. I can see it in my brain.	Visualization	Comprehension
I would picture what I need to be, the order and what factors I need to use.	Visualization	Comprehension

Table 9 (Continued)

Data Examples, Themes, and Conceptual Patterns from Open-ended Interviews

Data Examples	Themes	Conceptual Patterns
And it makes sense in my head what to put on the unit path. I visualize the unit path and drawing a long line and way over here what I want, circle it, and that gets me off on the right track (making motions with hands in a horizontal manner).	Visualization	Comprehension
I can see where I'm trying to get to and I can see where I start out and I can see it step-by-step.	Visualization	Comprehension
I think that DA makes sense to me because it seems logical because you go step-by-step to cancel out things you don't need. It's just logical. I know my steps that I need to go through and if it doesn't come out right then I go back and recheck it to see if I have done something wrong.	Step-by-step Approach	Comprehension
I like DA because it is user friendly, there is a set way to do it and I can think through it.	Step-by-step Approach	Comprehension
DA gives me the tools that I need to solve problems. I know how to plug everything in.	Step-by-step Approach	Comprehension

Table 9 (Continued)

Data Examples, Themes, and Conceptual Patterns from Open-ended Interviews

Data Examples	Themes	Conceptual Patterns
With DA I totally understand and totally like it and it makes more sense to me because I'm understanding why and where and what we are doing.	Step-by-step Approach	Comprehension
I understand each component that I am putting into the problem. And I like how there are steps to each part and that helps you to understand each part and what you are doing.	Step-by-step Approach	Comprehension
With DA I can set it up in a way to where I know why I am setting it up the way that I am. That way when I read the problem I know that I need the given quantity, my supply on hand, and my wanted quantity.	Step-by-step Approach	Comprehension
I understand exactly what I am doing when I am setting it up. With DA I understand why I am setting it up. I can just plug everything in and that helps me to understand.	Step-by-step Approach	Comprehension

Table 9 (Continued)

Data Examples, Themes, and Conceptual Patterns from Open-ended Interviews

Data Examples	Themes	Conceptual Patterns
For me that is what DA is, it is just black and white. I have my problems set up the way it is supposed to be. As long as you have your unit path and everything set up the way it is suppose to be, you plug in what you need, multiply and divide.	Step-by-step Approach	Comprehension
Whereas now, I can use DA and set up my problem, the way I know it has to be set up, totally understanding it. I feel you still have to think but now I know what I am doing and how to think it through.	Step-by-step Approach	Comprehension
I understand what I am putting into the unit path, my conversion factors, that all makes sense to me to get from A to B you have to use C.	Step-by-step Approach	Comprehension
I think with DA everything is in a closer range (hands showing a horizontal motion) and I just love the cancellation. I like DA because it is organized. It seems very organized to me. I am pretty much a step-by-step person and that is why it is easier for me. DA helps me to break out the pieces of what I need for the problem.	Step-by-step Approach	Comprehension

Table 9 (Continued)

Data Examples, Themes, and Conceptual Patterns from Open-ended Interviews

Data Examples	Themes	Conceptual Patterns
I know with DA that if I do this and I do this and I follow these steps, I know that I am going to get the answer, so there is a concrete end, there is a solution to the problem.	Step-by-step Approach	Comprehension
I took things step-by-step and gradually developed the answer by using DA. It helped me tremendously, before I was never quite sure how to set up a problem. And using DA I could do it.	Step-by-step Approach	Comprehension
I look at the problem, what is the given amount and where am I going to plug this in and is this going to match with this, it is a step-by-step thing and I know the steps so it is easier for me to plug in where I need to plug in. It is easier for me to do that.	Step-by-step Approach	Comprehension
I always have to use a calculator. I have to sit there and break it out, write things down and work through them.	Step-by-step Approach	Comprehension

Table 9 (Continued)

Data Examples, Themes, and Conceptual Patterns from Open-ended Interviews

Data Examples	Themes	Conceptual Patterns
I think that knowing how to solve the problem goes with the cancellation. That is how I know if I am on the right track, if I can cancel it out. Once I understood the conversions, it was real easy for me to cancel and solve the problem.	Step-by-step Approach	Comprehension
Because when you set up the unit path and you know what you are looking for and you know where to put it, like if you are looking for a milliliter and then you put milliliter on the top and you circle it and your answer is going to be in milliliters.	Step-by-step Approach	Comprehension
I would say for me that knowing I am on the right track and canceling out is a very effective way because I can tell if I am on the right track or what I need to do next or what I haven't done yet.	Step-by-step Approach	Comprehension
I understand the conversions. The conversions have to fit into the problem to cancel other things out so that I can have what I need in my unit path.	Step-by-step Approach	Comprehension

Table 9 (Continued)

Data Examples, Themes, and Conceptual Patterns from Open-ended Interviews

Data Examples	Themes	Conceptual Patterns
I definitely have severe or more than severe math anxiety. I feel a lot more confident now, I mean I know that I can do it and that gives me confidence.	Confidence	Positive Feelings
I have more confidence now. I am still kind of nervous about checking out but as long as I take my little cheat sheet with me and take my time and set it up correctly and double check my answers then I think I'll be OK.	Confidence	Positive Feelings
I never saw there being a definite answer with math, it could be this or it could be that, I never had the confidence before to know this is the answer.	Confidence	Positive Feelings
I just do it and it makes me feel confident that I am not going to mess up. It is just such easy steps and it just makes me feel better knowing that, so it feels good.	Confidence	Positive Feelings
I feel a lot more confident knowing my little unit path. So long as I have that I feel confident and I think it is a good thing.	Confidence	Positive Feelings
I know that as long as I set it up right I have greater confidence in my skills, that gives me the edge I think.	Confidence	Positive Feelings

Table 9 (Continued)

Data Examples, Themes, and Conceptual Patterns from Open-ended Interviews

Data Examples	Themes	Conceptual Patterns
DA has decreased my anxiety level, it is way down, way, way down. Before if I was going into a test knowing that it was all going to be math problems, my anxiety would be so up that I wouldn't be able to sit there even after meditating and do those problems correctly.	Reduced Anxiety	Positive Feelings
I think DA lowers my anxiety level but my anxiety is still there. I have high anxiety levels but DA helps with my anxiety.	Reduced Anxiety	Positive Feelings
In surgery as a tech I had to figure out heparin problems and it just totally and completely stressed me. I had people that tried to explain it to me but once I got to DA, now it makes sense. Heparin problems don't stress me out much anymore. It's nice to know how to do it.	Reduced Stress	Positive Feelings

Additional Findings from the Open-ended Interviews

Several additional findings were obtained from the open-ended interviews. One student stated that as the difficulty of the medication calculation problems increased, the level of anxiety that she was experiencing also increased. One student reported that she experienced extremely high levels of anxiety because she had started out using dimensional analysis and then was encouraged by another instructor to use ratio-and-proportion. When the difficulty of the medication calculation problems increased, she did not know how to use ratio-and-proportion and converted back to dimensional analysis as a problem-solving method. Two other students identified that their anxiety was connected to the fact that they knew they were responsible for giving medications to patients and that if the medication was not administered in the correct amount the lives of the patients would be endangered. Table 10 displays the responses from the nursing students regarding anxiety.

Table 10

Student Responses Regarding Anxiety Related to Complexity of Problems and Patient Safety

Interviewee	Data Examples
Interviewee #2	The first part of DA was OK but then we got into two-factor and three-factor problems and I would say at that point that my anxiety was moderate. It's the same formula, the same set-up but the more factors that you put in, the more nervous I get.

Table 10 (Continued)

Student Responses Regarding Anxiety Related to Complexity of Problems and Patient Safety

Interviewee	Data Examples
Interviewee #6	I think DA totally decreased my anxiety. At the beginning it didn't, when I first came to you with R/P and trying to convert back to DA, I had extremely high anxiety but once you worked with me and helped me then I wasn't worried about it at all. I think that DA totally makes sense and decreases anxiety. When I used R/P for solving these problems, I was totally confused.
Interviewee #2	I was never so math frightened or had such math anxiety until I got into nursing knowing that my calculations could theoretically kill someone. That is kind of scary. If you can't get it right, you are not going to be a nurse for long.
Interviewee #5	I knew that I would have to calculate dosages because that is what a nurse does but when you throw up math problems and you have to get the right dose, I thought "There's no way."

Another additional finding obtained from the open-ended interviews involved the use of ratio-and-proportion as a problem-solving method. Three students identified that they had used ratio-and-proportion in the past and had memorized how to set up the problems but had never understood what they were doing. Table 11 displays the responses from the nursing students regarding ratio-and-proportion.

Table 11

Student Responses Regarding Ratio-and-Proportion

Interviewee	Data Examples
Interviewee #2	I think it is good that I learned this. If you are using an X, there you are dealing with unknowns and this you know exactly what you are shooting for. I have always hated ratio and percentages because it was always harder for me to visualize them. I think that solving for X is more complicated. You read from left to right and it kind of makes more sense with using DA and it's laid out for you.
Interviewee #5	A lot of times I would just look at an example in the book and think well this is worded like this so this is probably how you have to set it up. But with DA, I can set it up in a way to where I know why I am setting it up the way that I am.
Interviewee #6	R/P worked for me but I didn't understand why it worked, I just kind of came up with the right answer. When I was taught R/P, it was just like a memorization and I memorized how to do it and didn't really understand it. I didn't really understand why I was setting it up the way it was. And that's why I would panic with R/P because I would set it up but I didn't really understand it so I couldn't double check, go through my mind and see if I was doing it the right way. But with DA I understand where things need to go but before it was just here it is, memorize it, this is how you do , but I never really understood why I was setting it up the way I was or what went where really.

Closed-ended Questionnaire

All of the nursing students who attended the didactic presentations (n=27) were asked to complete a 20-item, closed-ended questionnaire (Appendix D) to obtain additional information regarding the effectiveness of dimensional analysis as a problem-solving method. The first four statements included on the closed-ended questionnaire addressed the four sub-questions that also were presented to the six students during the one-to-one open-ended interviews. Questions #5 through #19 dealt with evaluating the teaching strategy used in the textbook entitled *Clinical Calculation using Dimensional Analysis* (Craig, 1997). Students were instructed to choose "Not Applicable" as an indicator for statements dealing with the textbook if they did not purchase the textbook. Question #20 evaluated whether or not the use of music, color, and peripheral learning charts maximized the learning process.

Utilizing a Likert Scale, students were asked to respond to the statements on the questionnaire by choosing the appropriate indicator for their answers based upon five categories:

1. Strongly Agree
2. Agree
3. Disagree
4. Strongly Disagree
5. Not Applicable

To analyze the data obtained from the closed-ended questionnaires, a descriptive analysis of each of the 20 statements was completed. Table 12 provides an analysis of the data obtained from the nursing students regarding the four sub-questions.

An analysis of Question #1 determined that 100% of the nursing students (n=27) concluded that dimensional analysis did indeed improve their mathematical calculation abilities (twelve students [44.4%] strongly agreed and 15 students [55.6%] agreed). Information obtained from the students regarding Question #2 also concluded that 100% of the nursing students (n=27) thought that dimensional analysis improved their conceptual abilities (the ability to set up mathematical problems in a logical manner). Fourteen students (5.1.9%) strongly agreed and 13 students (48.1%) agreed. Question #3 addressed the effectiveness of dimensional analysis and cognitive abilities (knowledge and understanding of how to solve mathematical problems). The data obtained from the nursing students revealed that 92.6% of the students (n=27) strongly agreed and agreed that dimensional analysis improved their cognitive abilities (11 students [40.7%] strongly agreed and 14 students [51.9%] agreed). Two students (7.4%) disagreed with the statement. The last sub-question (Question #4) dealt with student anxiety when solving mathematical calculation problems. Nine students (33.3%) strongly agreed and 12 students (44.5%) agreed that dimensional analysis reduced their anxiety level when solving mathematical calculation problems. Four students (14.8%) disagreed with the statement and one student (3.7%) strongly disagreed with the statement. One student (3.7%) answered not applicable.

Table 12

Data from the Closed-ended Questionnaire Regarding the Sub-Questions

Indicator	Question #1		Question #2		Question #3		Question #4	
	(N)	(%)	(N)	(%)	(N)	(%)	(N)	(%)
Strongly Agree	12	44.4	14	51.9	11	40.7	9	33.3
Agree	15	55.6	13	48.1	14	51.9	12	44.5
Disagree					2	7.4	4	14.8
Strongly Disagree							1	3.7
Not Applicable							1	3.7
(N) (%)	27	100	27	100	27	100	27	100

To evaluate the effectiveness of the teaching strategy as outlined in the textbook entitled *Clinical Calculations using Dimensional Analysis* (Craig, 1997), the students were asked to answer Questions #5 through #19 regarding the content, examples, and illustrations used in the textbook. The students were not required to buy the textbook and therefore were instructed to choose "Not Applicable" as an indicator for statements that specifically addressed the textbook if they did not purchase it. The data obtained were slightly confusing as to how many students may have purchased the textbook (six to ten students). Other students may have evaluated the supplemental Powerpoint handouts that were provided for the students in place of the textbook. Regardless, the majority of the students indicated that they strongly agreed or agreed with the statements regarding the textbook or chose "Not Applicable" as the indicator. Table 13 displays the data obtained from the nursing students regarding the evaluation of the teaching strategy as outlined in the textbook.

Table 13

Data from the Closed-ended Questionnaire Regarding the Teaching Strategy as outlined in the Textbook

Question	Strongly Agree		Agree		Disagree		Strongly Disagree		Not Applicable		Totals	
	(N)	(%)	(N)	(%)	(N)	(%)	(N)	(%)	(N)	(%)	(N)	(%)
#5	6	22.2	6	22.2	0		1	3.7	14	51.9	27	100
#6	5	18.5	5	18.5	1	3.7	0		16	59.3	27	100
#7	14	51.9	11	40.7	1	3.7	0		1	3.7	27	100
#8	3	11.1	5	18.5	0		0		19	70.4	27	100

Table 13 (Continued)

Data from the Closed-ended Questionnaires Regarding the Teaching Strategy as outlined in the Textbook

Question	Strongly Agree		Agree		Disagree		Strongly Disagree	Not Applicable		Totals	
	(N)	(%)	(N)	(%)	(N)	(%)	(N)	(N)	(%)	(N)	(%)
#9	8	29.6	1	3.7	0		0	18	66.7	27	100
#10	4	14.8	7	25.9	0		0	16	59.3	27	100
#11	11	40.7	6	22.2	2	7.5	0	8	29.6	27	100
#12	4	14.8	9	33.3	0		0	14	51.9	27	100
#13	6	22.2	5	18.5	0		0	16	59.3	27	100
#14	7	25.9	9	33.3	0		0	11	40.8	27	100
#15	8	29.6	11	40.8	0		0	8	29.6	27	100
#16	12	44.5	9	33.3	0		0	6	22.2	27	100
#17	6	22.2	11	40.8	1	3.7	0	9	33.3	27	100
#18	0		5	18.5	1	3.7	0	21	77.8	27	100
#19	2	7.4	4	14.8	0		0	21	77.8	27	100

Question #20 addressed the use of music, color, and peripheral learning charts as a means of promoting desensitization and a positive environment to maximize learning. Over one-half of the class (62.9%) strongly agreed and agreed that music, color, and the peripheral learning charts did maximize their learning process. Table 14 displays the responses from the students regarding the use of music, color, and peripheral learning charts to maximize learning.

Table 14

Data from the Closed-ended Questionnaire Regarding Music, Color, and Peripheral Learning Charts

Indicator	Question #20	
	(N)	(%)
Strongly Agree	8	29.7
Agree	9	33.3
Disagree	1	3.7
Strongly Disagree	0	
Not Applicable	9	33.3
(N) (%)	27	100

Summary

To determine the effectiveness of dimensional analysis as a problem-solving method from the nursing student perspective, a grand-tour question and four sub-questions were presented to a sample of 27 nursing students in a three-year diploma nursing education program from a hospital-based school of nursing located in central Iowa. To assist with triangulation of the data to draw conclusions from multiple referents, participant observation, one-to-one open-ended interviews, and a closed-ended questionnaire were utilized. Videotaping equipment was placed in the front of the classroom to observe the students for the non-verbal reactions of anxiety and confusion, as well as student interaction and attentiveness. A trained observer was positioned in the back of the classroom to observe for signs of anxiety and confusion, student interaction, and attentiveness.

Six nursing students were invited to participate in one-to-one, open-ended interviews answering the grand-tour question and four sub-questions. Nine emerging themes (negative feelings, adult learners, limited mathematical background, right-brain learner, visualization, step-by-step approach, confidence, reduced anxiety, and reduced stress) were obtained from the data examples provided by the six students during the open-ended interviews and categorized into three major conceptual patterns (lack of mathematical abilities, comprehension, and positive feelings).

Additional information obtained from the open-ended interviews provided insight into increased anxiety levels. Students reported that anxiety levels increased as the complexity of the medication calculation problem increased. Students also reported that they had increased anxiety levels if multiple problem-solving methods are encouraged by faculty. Finally, students agreed they experienced increased anxiety levels because they are acutely aware of the issue of patient safety.

Insight also was provided by the students regarding problem-solving with ratio-and-proportion. Students clarified that past success with ratio-and-proportion was based on their ability to memorize the formula but they admitted they lacked an understanding of how or why problems were set up in a particular manner.

Closed-ended questionnaires were answered by 27 nursing students. The first four statements on the questionnaire were the same four sub-questions proposed to the students during the one-to-one, open-ended interviews. All of the nursing students strongly agreed and agreed (100%) that dimensional analysis improved their mathematical calculation abilities and conceptual abilities. The nursing students strongly agreed and agreed (92.6%) that dimensional analysis improved their cognitive abilities. The nursing students strongly agreed and agreed (77.8%) that dimensional analysis reduced their anxiety levels when solving medication calculation problems.

Responses obtained from the closed-ended questionnaire (Questions #5 to #19) also provided information regarding the effectiveness of the teaching strategy used during the research from the textbook, *Clinical Calculations using Dimensional Analysis* (Craig, 1997). The data showed that six to ten students may have purchased the textbook or that the students may have evaluated the supplemental Powerpoint handouts that they received in support of the didactic presentations. Regardless of the reason, the majority of the students indicated that they strongly agreed or agreed with the statements or chose "Not Applicable" as an indicator.

Over one-half of the class (62.9%) strongly agreed and agreed that music, color, and peripheral learning charts maximized their learning process (Question #20). Chapter five discusses the analysis of the data obtained from the nursing students.

Chapter 5
SUMMARY, DISCUSSION, AND RECOMMENDATIONS

The purpose of this study was to answer the grand-tour question, "What perceptions do nursing students have regarding the effectiveness of dimensional analysis as a problem-solving method for medication calculations?" To explore the perceptions of the nursing students regarding their perceptions of dimensional analysis as a problem-solving method for medication calculations, a qualitative evaluation study was designed. The sample size included 27 nursing students from a three-year diploma nursing education program in a hospital-based school of nursing located in central Iowa. Based on the nursing literature regarding the mathematical, conceptual, and cognitive difficulties that nursing students experience, as well as the mathematical anxiety levels, four sub-questions also were included:

1. What perceptions do nursing students have regarding dimensional analysis and their mathematical calculation abilities?
2. What perceptions do nursing students have regarding dimensional analysis and their conceptual abilities?
3. What perceptions do nursing students have regarding dimensional analysis and their cognitive abilities?
4. What perceptions do nursing students have regarding dimensional analysis and their anxiety levels?

To establish trustworthiness of the study, triangulation of data was accomplished through the use of participant observation (videotaping and a trained observer), one-to-one, open-ended interviews, and a closed-ended questionnaire. Data obtained from the nursing students provided themes and conceptual patterns regarding the effectiveness of dimensional analysis as a problem-solving method for medication calculations.

Critical case sampling was utilized by inviting six nursing students who were continuing to experience difficulty with medication calculations to participate in one-to-one, open-ended interviews utilizing the grand-tour question and the four sub-questions. The six students interviewed all agreed that dimensional analysis was an effective problem-solving method for solving medication calculation problems. The demographics of the six students were homogeneous in that they had a limited amount of high school mathematical education (one to three years) that resulted in varying levels of anxiety when placed in situations where mathematical calculation was necessary. Only one student had four plus years of mathematics but still identified a moderate level of anxiety. When using dimensional analysis, the students expressed feelings of safety and security in knowing how to solve a mathematical problem which reduced their anxiety levels (Chapter 4, Tables 8 and 9).

Based on the data examples provided by the six students when answering the grand-tour question and sub-questions during the interviews, three conceptual patterns were identified:

1. Lack of Mathematical Abilities
2. Comprehension
3. Positive Feelings

The pattern "lack of mathematical abilities" was supported by four consistent themes obtained from the data examples. The first theme in this pattern involved the identification of negative feelings regarding mathematics expressed by the nursing students. The second theme identified the fact that several of the students were adult learners that had been out of school for many years and had forgotten their mathematical skills. The third theme in this pattern identified that several of the students had limited mathematical backgrounds. The final theme expressed by the nursing students involved the clarification by several of the students that they were better in the arts and sciences and had never been able to understand mathematics.

The pattern "comprehension" was supported by two consistent themes obtained from the perceptions of the nursing students regarding dimensional analysis and their conceptual and cognitive abilities. The themes obtained from the students for this pattern were overlapping in that the reason the students understood how to solve a problem with dimensional analysis involved the ability to visualize the problem-solving method that allowed them to follow logical steps to solve the problem. The ability to set the problem up in a logical manner also provided the students with a system to recheck their answer for accurateness.

The remaining themes expressed by the nursing students when discussing their perceptions of dimensional analysis and anxiety levels involved an expression of increased confidence, reduced levels of anxiety, and reduced stress. These themes were placed in the pattern "positive feelings."

Additional information obtained from the responses by the nursing students during the one-to-one, open-ended interviews provided insight into increased anxiety levels resulting from three different types of situations. Students commented during the interviews that anxiety levels increased as the difficulty of the medication problem advanced from simple (one-factor problems) to complex (multi-step and three-factor problems). One student expressed increased anxiety because she had started out problem-solving with dimensional analysis and then was encouraged by another instructor to use ratio-and-proportion because that was the problem-solving method the instructor used for calculating medication problems. When the complexity of the medication calculation problems increased, she did not know how to use ratio-and-proportion and was no longer with the instructor who used ratio-and-proportion. She requested additional one-to-one tutoring and converted back to using dimensional analysis as a problem-solving method. Finally, two students identified that their anxiety levels increased because they were acutely aware of the issue of patient safely.

Insight was additionally provided by several students regarding the difficulties of medication calculation problem-solving with ratio-and-proportion. Students admitted memorizing the formula for solving problems with ratio-and-proportion but confessed that they never really understood how or why problems were set up.

Closed-ended questionnaires were completed by 27 nursing students using a Likert scale to indicate their responses (strongly agree, agree, not applicable, disagree, and strongly disagree) to 20 statements (Appendix 8). The first four statements on the questionnaire were the four sub-questions used during the one-to-one, open-ended interviews. All the nursing students strongly agreed and agreed (100%) that dimensional analysis improved their mathematical calculation abilities and conceptual abilities. The nursing students strongly agreed and agreed (92.6%) that dimensional analysis improved their cognitive abilities (11 students [40.7%] strongly agreed and 14 students [51.9%] agreed). The nursing students strongly agreed and agreed (77.8%) that dimensional analysis reduced their anxiety levels when solving mathematical calculation problems (nine nursing students [33.3%] strongly agreed and 12 students [44.5%] agreed).

The closed-ended questionnaire (Questions #5 through #19) also provided an opportunity for the students to evaluate the teaching strategy used to teach dimensional analysis by providing feedback regarding the content, examples, and illustrations utilized in the textbook entitled *Clinical Calculations using Dimensional Analysis* (Craig, 1997). Regardless of whether or not the students purchased the textbook or used the supplemental Powerpoint handouts, the majority of the students indicated that they strongly agreed or agreed with the statements regarding the teaching strategy used in the textbook and classroom to teach dimensional analysis.

In an effort to address the issue of desensitization and promotion of positive attitudes regarding mathematics, the students also were asked to evaluate the use of music, color, and peripheral learning charts to maximize the learning process (Question #20). The students strongly agreed and agreed (62.9%) that music, color, and peripheral learning charts maximized their learning.

Discussion

The grand-tour question, "What perceptions do nursing students have regarding the effectiveness of dimensional analysis as a problem-solving method for medication calculations?" was answered by a critical case sampling of six nursing students during one-to-one, open-ended interviews. All six nursing students agreed that dimensional analysis was an effective problem-solving method. When using dimensional analysis, the students expressed feelings of safety and security in knowing how to solve a mathematical problem which in turn reduced their anxiety levels (Chapter 4, Tables 8 and 9). The perceptions expressed by the nursing students also were visible during the didactic presentations from N130 (first year introductory basic nursing course) to N330 (a thind year family adaptation nursing course) as more student interaction and involvement was noticed in N330 both by the camera and the trained observer (Chapter 4, Tables 2 through 6).

The perceptions expressed by the nursing students that dimensional analysis is an effective problem-solving method is consistent with the information available in the chemistry literature (Gabel & Sherwood, 1983; Hauben & Lehman, 1988) and the nursing literature (Craig & Sellers, 1995) that concluded that dimensional analysis is a valuable method for teaching medication calculation for solving problems that require numerous steps and conversions.

Gabel and Sherwood (1983) identified that dimensional analysis was the most effective method for teaching the mole concept to chemistry students. The mole concept is similar to the type of medication dosage calculation problems that nurses or nursing students encounter in clinical practice. Both types of problems require numerous steps and conversions to be able to obtain an answer.

Hauben and Lehman (1988) recognized dimensional analysis as an effective problem-solving method and focused on determining which type of methodology was most desirable when teaching dimensional analysis to chemistry students. Despite the methodology utilized by the experimental group (Computer Assisted Instruction) or the control group (paper and pencil modules), both groups were positive in their ratings of dimensional analysis as an effective problem-solving method.

Craig and Sellers (1995) researched dimensional analysis and found that it significantly improved the medication calculation abilities of diploma nursing students. The findings of the study support the use of dimensional analysis as an effective problem-solving method to assist nursing students in developing mathematical and conceptual skills to accurately calculate medication dosage problems and ensure the safe administration of medications.

The first sub-question, "What perceptions do nursing students have regarding dimensional analysis and their mathematical calculation abilities?" was answered by six nursing students during one-to-one, open-ended interviews. Through use of a closed-ended questionnaire, 27 nursing students replied to the statement, "Dimensional analysis improved my mathematical calculation abilities. All the nursing students completing the closed-ended questionnaire strongly agreed and agreed (100%) that dimensional analysis improved their mathematical calculation abilities.

During the one-to-one, open-ended interviews, four consistent themes emerged from the data examples provided by the six nursing students and were used to identify the conceptual pattern "lack of mathematical abilities." The first theme in the pattern "lack of mathematical abilities" involved the identification of negative feelings regarding mathematics expressed by the nursing students. As one student succinctly put it, "Math was just a big barrier, a huge barrier."

This finding is consistent with articles published in the nursing literature (Chenger et al., 1988; Flynn & Moore, 1990; Pozehl, 1996). Chenger et al. (1988) determined that positive attitudes toward mathematics (defined as voluntarily selecting a mathematical course at the post secondary level) correlated with mathematical performance. Flynn and Moore (1990) agreed that attitude toward mathematics can predict mathematical performance. Pozehl (1996) recommended that educators explore potential methods of instruction to not only decrease student anxiety regarding mathematics but to promote positive attitudes toward mathematics. The positive feelings regarding mathematics that developed for these students after learning to solve medication calculation problems with dimensional analysis will be further discussed in this chapter in the pattern "positive feelings."

The second theme that emerged from the interviews regarding mathematical abilities involved the self-identification of three of the students as "adult learners." These students admitted that they had been out of school for many years and had forgotten their basic mathematical skills because they did not need to use them in their previous positions. One student clearly articulated that "if you don't use it, you lose it."

Knowles (1990) offered four definitions of adult learner including biological (reaching the age of reproduction); legal (reaching the age where the law deems that we can vote, obtain a driver's license, and marry without consent); social (performance of adult roles like full-time employment, spouse, parent, and voting citizen); and psychological (responsible and self-directing). According to Knowles, these students meet the criteria of "adult learner." An assumption also identified by Knowles is adults possess a "readiness to learn." These students knew they had to be able to calculate medication problems to safely administer medication to patients and were ready to learn. As one student explained, "If you can't get it right, you are not going to be a nurse for long."

The third theme that emerged from the interviews with the nursing students that was included in the pattern "lack of mathematical abilities" had to do with the limited mathematical background the students possessed. As one student put it, "I didn't have any math ability behind me at all."

This finding is consistent with the information in the nursing literature (Bindler & Bayne, 1984; Dexter & Applegate, 1980; Ptaszynski & Silver, 1981). Bindler and Bayne (1984) identified a substantial number of nursing students failed a basic mathematics proficiency test (the ability to add, subtract, multiply, and divide whole numbers, fractions, decimals, and percentages). Dexter and Applegate (1980) determined it would be possible to graduate a nursing student who was deficient in basic mathematics and set up guidelines to improve the mathematical skills of nursing students. Ptaszynski and Silver (1981) established that nursing students were entering nursing programs with varying degrees of mathematical ability and devised a program to bridge the gap between fundamental mathematics (decimals, fractions, and percentages) and complex dosage problems.

Regardless of the limited mathematical background that resulted in a lack of mathematical abilities, the nursing students who learned to solve medication calculation problems with dimensional analysis improved their mathematical abilities. The six nursing students who received additional one-to-one tutoring all obtained passing scores on a required course module with ten mathematical calculation problems not associated with this study. These were students who previously were not successful with mathematical calculations and now had the opportunity to experience mathematical success for the first time.

The final theme in the pattern "lack of mathematical abilities" that emerged from the interviews with the nursing students was that several students considered themselves better in the arts and sciences than mathematics. Typically the type of student more interested in the arts is considered a right-brain learner and the type of student interested in mathematics is considered a left-brain learner.

Much has been written about cognitive science (the study of the mind) and neuroscience (the study of the brain) in scientific and educational journals. Galaburda, LeMay, Kemper, and Geschwind (1978) identified that 80 to 90% of the population is left-hemisphere dominant and only 10 to 20% of the population is right-hemisphere dominant. They noted that left-brain learners may demonstrate verbal proficiency but have low visual-spatial skills and right-brain learners may have reading and spelling problems but have superior, visual-spatial skills. They concluded that this is a subject that should be considered by our educational systems.

Research continued regarding right-brain and left-brain learners with Grow and Johnson (1983) who speculated there are two kinds of people in the world--those who can do math and those who cannot. They identified right-brain learners who process information in a holistic, visual-spatial manner are at a disadvantage in schools where the curricula favor left-brain learning with a heavy emphasis on language skills. They encouraged schools to identify individual learning styles to better facilitate the educational process.

Clarifying the issue of right-brain and left-brain learners, Rose (1985) noted several researchers have studied the functions of the brain and found the right-brain primarily deals with music, visual impressions, pictures, spatial patterns, and color recognition whereas the left-brain principally deals with language, mathematical processes, logical thought, sequences, and analysis.

Holbert and Thomas (1988) stressed whole-brain education is the vehicle that will prepare learners of today for the challenges of the future. They identified that whole-brain education approaches are designed to develop thinking, learning, and behavioral skills with a strong emphasis on cognitive learning. They contend that to survive in the 21st century, learners must become life-long learners who are flexible and open to change.

Almost two decades after the recommendation from Galaburda et al. (1978), Gardner (1993) proposed that a school should be individual-centered and focus on optimal understanding and development of each student. He identified that at the present time most schools are set up with a "uniform view" that requires students to take courses in critical reading, calculation, and thinking skills that may pose a problem for right-brain learners. With his identification of seven intelligences, he warned against an exclusive focus on linguistic and logical skills but encouraged the use of spatial, interpersonal, or bodily-kinesthetic skills. He supported the use of alternative routes (learning mathematics via spatial relations) of teaching including learning mathematics to develop the cognitive profile of every student.

Bath and Blais (1993) found statistics similar to those reported by Galaburda et al. (1978) when they researched the learning styles of nursing students as a predictor of medication calculation abilities and concluded the majority of nursing students (83%) utilized a step-by-step process that required conceptualization of the mathematical problem. They agreed with Grow and Johnson (1983) that learning styles must be considered and reinforced through the use of one consistent, step-by-step problem-solving strategy throughout the curriculum.

The second and third sub-questions, "What perceptions do nursing students have regarding dimensional analysis and their conceptual abilities (the ability to set up a mathematical problem in a logical manner)?" and "What perceptions do nursing students have regarding dimensional analysis and their cognitive abilities (the knowledge and understanding of how to solve a mathematical problem)?" were answered by six nursing students during one-to-one, open-ended interviews. Through use of a closed-ended questionnaire (Appendix D), 27 nursing students replied to the statements, "Dimensional analysis improved my conceptual abilities." and "Dimensional analysis improved my cognitive abilities." All the nursing students completing the closed-ended questionnaire strongly agreed and agreed (100%) that dimensional analysis improved their conceptual abilities. The nursing students strongly agreed and agreed (92.6%) that dimensional analysis improved their cognitive abilities (11 students [40.7%] strongly agreed and 14 students [51.9%] agreed).

Dimensional analysis is a problem-solving method that assists learners to critically think their way through a problem and understand "how" a problem is solved regardless of whether they consider themselves right-brain or left-brain learners. This conclusion is evident in the responses to the second and third sub-questions. Two themes were identified from the data examples provided by the nursing students regarding dimensional analysis and their conceptual and cognitive abilities and were placed in the pattern "comprehension." The themes were repeated consistently by the students and a relationship was evident in that the themes were overlapping regarding conceptual and cognitive abilities. Students verbalized that dimensional analysis first allowed them to visualize the problem (a right-brain function) and following successful visualization to implement logical steps to solve the problem (a left-brain function). Not only were they able to solve the problem but they also were able to recheck their answers for accurateness (analytic thinking).

The first theme to emerge from the interviews with the nursing students and placed in the pattern "comprehension" involved the ability expressed by the students to visualize how to set up the medication calculation problem (Chapter 4, Table 9). Numerous references were made by the students regarding the need to "see" how to set up the medication problem and that dimensional analysis (specifically the unit path) provides them with a "picture."

Example of Unit Path:

Given Quantity	Conversion Factor for Given Quantity	Conversion Factor for Wanted Quantity	Conversion Computation	Wanted Quantity
1 liter	1000 ml	1 oz	1000 =	33.3 ounces
	1 liter	30 ml	30	

The video camera used during the one-to-one, open-ended interviews captured one nursing student using her hands in a horizontal manner to explain the unit path and the similarity with reading from left to right. One student stated clearly that "it's easier for me to understand a picture than to understand math." Another student expounded "Things have to be a picture for me, that is how I see it. When I am studying and I don't understand something, I take my son's crayons out and make a picture of it. I have to picture things in my head and if I can picture it, I can remember it." Both students could be identified as right-brain learners based on the description provided in the textbook written by Rose (1985) because both students utilize visual impressions and pictures to learn new concepts. During the didactic presentations both the trained observer and the video camera identified there were more student interactions and attentiveness when visual, hands-on examples of medication vials were provided for the nursing students to calculation medication problems (Chapter 4, Tables 4, 5, 6, and 7). Based on the responses of the students, two of the nursing students interviewed could be classified as right-brain learners, two students favored right-brain techniques but also acknowledged previous mathematical abilities, and two students could be classified as left-brain learners in that they had previous success with using logical thought to solve medication calculation problems. Based on the findings from this study, it could be concluded that dimensional analysis is an effective problem-solving method for medication calculations for multiple learning styles.

A step-by-step approach was the second theme identified in the pattern "comprehension." According to Rose (1985), a step-by-step approach is a left-brain function in that the left-brain deals specifically with logical thought, sequences, analysis, and mathematical processes. Students identified that dimensional analysis seemed logical because of the step-by-step process that is utilized to solve medication calculation problems as well as provide a system to recheck answers for accurateness. One student stated, "I think that dimensional analysis makes sense to me because it seems logical because you go step-by-step to cancel out things you don't need. It's just logical. I know my steps that I need to go through and if it doesn't come out right, then I go back and recheck it to see if I have done something wrong." Another student responded, "I like dimensional analysis because it is user friendly, there is a set way to do it, and I can think through it."

These findings are consistent with the cognitive learning theory proposed by Bruner (1960). He focused on "how" to learn, rather than "what" to learn and concluded that the ability to proceed a step at a time with explicit steps that can be adequately reported by the thinker to another individual is analytic thinking. Students problem-solving with dimensional analysis are using the type of analytic thinking described by Bruner. This type of thinking was described by Rose (1985) as a left-brain function.

These findings also are consistent with the definition given by Hein (1983) when he concluded that dimensional analysis provides a systematic, straightforward way to set up problems. He clarified that dimensional analysis provides a clear understanding of the principles of the problem, helps the learner to organize and evaluate data, and assists in identifying errors in that unwanted units are not eliminated if the setup of the problem is incorrect. Conceptual errors (set-up of the problem) were an issue that Blais and Bath

(1992) identified as a serious problem in their research. They recommended that schools of nursing focus on problem-solving strategies that assist the student to conceptualize the dosage calculation problem. Segatore, Edge, and Miller (1993) agreed that set-up errors (failure to provide, or inability to set up the correct formula) and form errors (failure to provide the correct form of medication) were problems that existed and recommended that attention be paid to the rationale behind the use of formulas. Dimensional analysis was effective in assisting the nursing students conceptualize the dosage calculation problem as well as understand the rationale behind this problem-solving method when calculating medication problems.

The final sub-question presented to the six nursing students in the one-to-one, open-ended interviews queried, "What perceptions do nursing students have regarding dimensional analysis and their anxiety levels?" A similar statement used on the closed-ended questionnaire requested a reply to the statement, "Dimensional analysis reduced my anxiety level when solving mathematical calculation problems." Nine students (33.3%) strongly agreed and 12 students (44.5%) agreed that dimensional analysis reduced their anxiety levels when solving mathematical calculation problems. Four students (14.8%) disagreed with the statement and one student (3.7%) strongly disagreed with the statement.

The three themes (increased confidence, reduced anxiety, and reduced stress) emerged from the data examples obtained from the nursing students during the one-to-one, open-ended interviews and were placed in the final pattern "positive feelings." Increased confidence was a theme expressed by five of the six students regarding their perceptions of problem-solving with dimensional analysis. One student stated, "I definitely have severe or more than severe math anxiety. I feel a lot more confident now, I mean I know that I can do it and that gives me confidence." Another student verbalized "I feel a lot more confident knowing my little unit path. So long as I have that, I feel confident and I think it is a good thing." Another student remarked that "Dimensional analysis has decreased my anxiety level, it is way down, way, way down." But anxiety is an emotion that is not easily overcome as clarified by yet another student "I think dimensional analysis lowers my anxiety level but my anxiety is still there. I have high anxiety levels but dimensional analysis helps with my anxiety." Finally, one student explained that problems "just totally and completely stressed me" but that after learning how to solve a medication dosage problem with dimensional analysis she stated "problems don't stress me out much anymore."

These statements are congruent with research by Hauben and Lehman (1988) who asked chemistry students to rate their attitude regarding dimensional analysis and found that students were very positive in their ratings of dimensional analysis. Although anxiety was not identified as a serious issue, Pozehl (1996) recommended nursing educators create a learning environment that will help students obtain a positive attitude regarding mathematics by exploring methods of instruction that will decrease anxiety.

The nursing students in this study perceived that dimensional analysis does indeed reduce anxiety levels and promote positive feelings regarding medication calculations. Although four students (14.8%) disagreed and one student (3.7%) strongly disagreed with the statement, the students also verbalized feelings of confidence and reduced anxiety.

Perhaps preexisting anxiety regarding mathematical calculations can only be reduced to a manageable level but not eliminated. Two of the nursing students expressed deeply rooted feelings of negativism regarding mathematics that will only be overcome with continued practice and success.

Questions #5 through #19 were included on the closed-ended questionnaire to provide an opportunity for the nursing students to evaluate the teaching strategy used in the classroom based on the content, examples, and illustrations utilized in the textbook entitled *Clinical Calculations using Dimensional Analysis* (Craig, 1997). Students were instructed to choose "Not Applicable" as an indicator if they did not purchase the textbook. Some confusion may have existed in that students received supplemental Powerpoint handouts during each didactic presentation and may have evaluated these handouts as part of the textbook. Regardless of whether or not the students evaluated the textbook or the supplemental Powerpoint handouts, the statements regarding the teaching strategy used in the textbook were positive in that the majority of students strongly agreed or agreed with the statements. Although the questionnaire was reviewed by faculty members, this was the first time that this questionnaire was used to gather information and, therefore was not well established as an instrument.

Question #20 was included on the questionnaire to provide the nursing students with an opportunity to evaluate the use of music, color, and peripheral learning charts used in the classroom to promote a positive learning environment. The students strongly agreed and agreed (62.9%) that music, color, and peripheral learning charts did indeed maximize their learning in a positive environment. One student (3.7%) disagreed and nine students (33.3%) chose "Not Applicable" as an indicator.

Schuster and Gritton (1987) identified that the use of baroque music (4/4 rhythm with 60 beats per minute) assisted students to learn better because the use of music in the classroom is unusual and therefore has a Hawthorne placebo effect. They also suggested that it helps students to relax which in turn assists with learning. Finally, they clarified that the rhythm of the music provides input to the right brain hemisphere that promotes whole brain learning. Typically when solving mathematical calculations (a left-brain function), a right-brain learner may not be actively engaged in learning but with the use of music, engagement in the learning process is promoted. Rose (1985) clarified that music works by stimulating the right side of the brain which in turn results in the left brain and right brain being directly and independently stimulated. He proposed that to create a stress-free learning environment, words, pictures, and music must be coordinated to result in left-brain and right-brain engagement.

Knowles (1990) suggested that establishing a climate conducive to learning is an important issue for the andragogical teacher when facilitating the education of adult learners to avoid blocks to learning. He clarified that ecological psychologists identified that color directly influences the mood of the student and that bright colors induce cheerful, optimistic moods which in turn place the learner in a more receptive learning mode.

In this study, nursing students found that dimensional analysis was an effective problem-solving method for medication calculations that assisted them in improving their mathematical, conceptual, and cognitive abilities, as well as decrease their anxiety levels. Dimensional analysis was found to be successful for both right-brain and left-brain learners because of its ability to be visualized and followed in a logical manner with an explicit step-by-step approach. This positive finding certainly warrants further research using dimensional analysis as a problem-solving method for medication calculations with other nursing students, students in other disciplines, and practicing nurses.

Limitations

The most significant limitation of the study was the sample. The sample was small, selected through purposeful sampling (n=27) and sampling of critical cases (n=6) and not representative of diploma nursing students or any nursing student. Thus, the findings from this study are limited.

Another major limitation of the study was the credibility and dependability of the closed-ended questionnaire. Although the questionnaire was reviewed by faculty members and the major advisor, the questionnaire was researcher-developed and had not been piloted. The closed-ended questionnaire was not well established. This limitation needs to be considered when evaluating the student responses obtained from the questionnaire.

An additional major limitation of the study was the multiple roles the researcher had in the study (teacher, researcher, and textbook author) that could biased the study and had a halo effect on the subjects in the study. This limitation needs to be considered when evaluating the responses of the students obtained from the one-to-one, open-ended interviews and the closed-ended questionnaire.

Another limitation of the study was the timing of the administration of the closed-ended questionnaire. The students were requested to complete the questionnaire at the end of the Nursing 330 didactic presentation. Although instructions for completing the questionnaire were given to the nursing students, they quickly filled out the questionnaire so they could meet prior commitments. This limitation also needs to be considered when evaluating the student responses obtained from the questionnaire.

A final limitation of the study may have been the use of the video camera during the one-to-one, open-ended interviews. Although the main reason for the use of the video camera was to record the verbal responses of the nursing students, it also was used to evaluate the non-verbal responses of the nursing students. One student, however, verbalized discomfort sitting in front of the video camera. Although she was assured that the researcher was the only one who would view the videotape, her interview was brief with no additional elaboration on any of the responses to the mini-tour or four sub-questions used during the interview.

Recommendations for Future Research

Although critical case sampling was utilized for this qualitative study, the researcher recommends that the study be repeated exploring the perceptions of nursing students from different ethnic backgrounds regarding the effectiveness of dimensional analysis for medication calculation with a maximum variation sampling. This would allow for a wider range of responses from culturally diverse students who have previously used dimensional analysis as a problem-solving method for mathematical calculations, students who have never used dimensional analysis as a problem-solving method for mathematical calculations but have successfully used another method, and students who have never been successful with mathematical calculations using any problem-solving method.

Another recommendation for future research would be to repeat this qualitative study exploring the perceptions of nursing students where the researcher did not have multiple roles. This would assist in eliminating the halo effect as a threat to the study.

Repeating the quasi-experimental quantitative study using an experimental pretest/post-test design also would be another recommendation. Examining the medication calculation abilities of associate, diploma, under-graduate, and graduate nursing students, as well as practicing nurses would provide a larger, more heterogeneous sample representative of the target nursing population.

Another recommendation for future research would be to evaluate the effectiveness of dimensional analysis by conducting a study combining qualitative and quantitative data collection techniques. This would allow for the evaluation of dimensional analysis as a problem-solving method for medication calculations by exploring the perceptions of the nursing students through thick, rich descriptions as well as obtain statistical data from a pretest/post-test design.

Reevaluating the perceptions of the six nursing students after they have been employed as registered nurses would be another recommendation for future study. This qualitative study would assist in evaluating if they continue to perceive that dimensional analysis is an effective problem-solving method for medication calculations once they have been practicing in the clinical setting. The study would assist in reexamining the perceptions of learners regarding the effectiveness of dimensional analysis as a problem-solving method with a group of learners who have previously been unsuccessful with mathematical calculations.

A final recommendation would be to identify staff nurses that are experiencing difficulty with medication calculations (numerous medication errors) and conduct a quasi-experimental quantitative research study to identify if dimensional analysis is an effective problem-solving method for teaching medication calculations to registered nurses. This study would assist in eliminating medication errors that threaten patient safety.

Implications for Advanced Nursing Practice

The nursing literature identified that mathematical and dosage calculation deficiencies have been a problem in nursing since 1979 (Perlstein et al.) and remain an ongoing problem (Ashby, 1997). This study was significant for advanced nursing practice because it provided additional support for teaching dimensional analysis as a problem-solving method to enhance the mathematical, conceptual, and cognitive abilities of nursing students. This is an important issue to nursing because of the legal and ethical responsibility of nurses regarding the administration of medications. Medication errors related to calculation deficiencies threaten patient safety and are costly in terms of malpractice litigation contributing to the excessive costs in the entire health care industry. The magnitude of medication errors may be compounded as more unlicensed personnel are included as members of the health care team and delegated the responsibility of administering medications. Although the responsibility for administering medication may be delegated to the unlicensed personnel, it remains the legal responsibility of the nurse in terms of malpractice litigation.

This study explored the perceptions of nursing students regarding the effectiveness of dimensional analysis as a problem-solving method for medication calculations and answered the question regarding whether or not dimensional analysis improved mathematical, conceptual, and cognitive abilities and decreased anxiety levels. Based on the findings from this study obtained from a sample of 27 nursing students in a diploma nursing program located in central Iowa, dimensional analysis was found to be an effective problem-solving method for medication calculations that improved mathematical, conceptual, and cognitive abilities as well as reduced anxiety levels. As a problem-solving method, this study supported dimensional analysis as a method to promote conceptualization of a problem through visualization and comprehension through a step-by-step approach. Therefore, dimensional analysis should be considered and adopted by schools of nursing to assist with alleviating medication errors in nursing practice.

Nurse educators are encouraged to integrate dimensional analysis throughout the curriculum using a simple to complex approach to ensure concept building and eliminate the confusion encountered by students when multiple methodologies are taught. This type of a curriculum design is consistent with the 1984 recommendation from the National Institute of Education that encouraged educators to increase the emphasis on problem solving, critical thinking, and the mastery of concepts rather than facts. It also is consistent with literature on curriculum revolution in nursing that recommended the seeing and understanding the significance of the whole (Bevis, 1988; Lindeman, 1989; Tanner, 1988). Dimensional analysis uses higher level thinking skills and concept building skills that are promoted in both higher education and nursing education.

Dimensional analysis also should be considered by staff development as a means of reducing medication errors and improving medication dosage calculation abilities of those administering medications in hospitals and various other settings requiring medication administration. Nurses or unlicensed personnel responsible for medication administration should be required to validate competency through the use of a yearly medication calculation competency module. Despite the differences in mathematical backgrounds, those experiencing difficulty with medication dosage calculations could be identified and assisted with improving their medication calculation abilities through the use of dimensional analysis as a problem-solving method.

The issue regarding medication errors has been researched and addressed as to why medication errors occur. Medication errors occur because of mathematical, conceptual, and cognitive deficiencies. Anxiety and stress have been identified as possible contributing factors to medication errors. Chemistry educators have indicated dimensional analysis has replaced ratio-and-proportion as a problem-solving method for mathematical calculations. Medication errors continue to be identified as an ongoing problem in nursing practice. Therefore, regardless of whether dimensional analysis is used in education or practice, it remains an avenue to be considered by schools of nursing, hospitals, or other institutions when the goal is competence in medication calculation abilities, reduction of medication errors, and above all adherence to the code "do no harm."

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APPENDIX A

Demographic Tool

Demographic Tool

Date: ______________________________

Identification Number: ____________________

To assist with this qualitative study, please provide the following information by circling the answer that best describes you:

Q-1. Identify your age category:
1. 18 - 22
2. 23 - 27
3. 28 - 35
4. 36 and above

Q-2. Identify your gender:
1. Male
2. Female

Q-3. How recently did you complete an introductory chemistry course in a community college or university?
1. Within the last two years
2. Within the last three to five years
3. Within the last six to ten years
4. More than ten years ago
5. Never enrolled in a chemistry course as part of my post-secondary education

Q-4. How many years of high school mathematics did you complete?
1. one
2. two
3. three
4. four
5. four plus post-secondary education

Q-5. How would you rate your anxiety level regarding mathematics?
1. No anxiety
2. Mild anxiety
3. Moderate anxiety
4. Severe anxiety

APPENDIX B

Cover Letter

September 30, 1996

Dear Student:

As a nurse and a nursing instructor, I am concerned about the mathematical calculation abilities of nursing students. Nursing students are expected to administer medication using the five rights of drug administration that includes the ability to correctly calculate medication problems.

The purpose of this qualitative study is to evaluate the effectiveness of dimensional analysis as a problem-solving method for medication calculations from the perspective of nursing students.The benefit of being involved in this study is being part of an extensive study focusing on improving medication dosage calculation abilities of nursing students. The study is being conducted in connection with my doctoral degree requirements at Drake University, Department of Education, Des Moines, Iowa.

Because you are a nursing student, you have been selected to participate in this study. In no way will your participation or non-participation in this study affect your grade or student status. Your participation in this study is entirely voluntary, and you are free to stop at any time. Your signature on the student informed consent will be your consent to participate in this study. In order to ensure your anonymity and protect confidentiality, you name should <u>not</u> be placed on the demographic tool, instead, please use the last four digits of your social security number.

If you would like a summary of the findings of this study, a copy can be obtained from the participating college or school of education. Further information about this study can be obtained by contacting my advisor, Charles S. Greenwood, EdD, at 515/271-2120. Thank you in advance for your participation in this study.

Sincerely,

Gloria P. Craig, RN, BSN, MSN, EdS

APPENDIX C

Student Informed Consent

Student Informed Consent

I have read and understand the attached cover letter and agree to participate in this qualitative study to evaluate the effectivenes of dimensional analysis as a problem-solving method for medication calculations from the perspective of nursing students. In no way will your participation or non-participation in this study affect your grade or student status. You will not be penalized if you choose not to participate in this study. Your signature on this form will be your consent to participate in this study.

______________________________ ____________________

Student Date

______________________________ ____________________

Researcher Date

APPENDIX D

Closed-ended Questionnaire

Closed-ended Questionnaire

Answer the following questions utilizing the following indicators:

A. Strongly agree
B. Agree
C. Disagree
D. Strongly disagree
E. Not applicable

Questions:

1. Dimensional analysis improved my mathematical calculation abilities.
2. Dimensional analysis improved my conceptual abilities (the ability to set up a mathematical problem in a logical manner).
3. Dimensional analysis improved my cognitive abilities (the knowledge and understanding of how to solve a mathematical problem).
4. Dimensional analysis reduced my anxiety level when solving mathematical calculation problems.
5. The content of the textbook was presented in a simple-to-complex organization using sound learning theory.
6. The content of the textbook used a step-by-step approach.
7. The examples of problem-solving provided clear explanation of how to set up and solve the problem.
8. The content of the textbook was presented in a readable manner.
9. The content of the textbook stimulated me to think critically.
10. The chapter objectives were clear and concise.
11. The "Thinking through the Problem" boxes were helpful in providing additional guidelines and tips for solving problems.
12. The terms used throughout the textbook were adequately defined.
13. The illustrations (drug labels and graphics) used throughout the book appropriately simulated the clinical setting experience.
14. The practice problems used throughout the textbook provided ample opportunity for student learning.
15. The post-test assisted in self-evaluation.
16. The case studies provided an opportunity to practice simulated physician orders.
17. The answer keys provided easy access and details of problem solving.
18. The appendices were helpful.
19. The index was complete.
20. The music, color, and peripheral learning charts used to teach dimensional analysis maximized the learning process.